Volume 1 and 2

The Organization and Management of Construction

10th International Symposium

CONSTRUCTION INNOVATION and GLOBAL COMPETITIVENESS

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FOREWORD: Volume 1

Innovation, Globalization and Competitiveness in the Construction Industry

The construction industry is one of the most important industries in any country. It is a dynamic industry that has the same characteristics in developed as in developing countries. Construction projects are complex with numerous issues that must be addressed before and during execution. Also, it is the only industry where workers intentionally work themselves out of a job. The projects are site specific and are constantly changing as the work progresses. These changes are what make the industry interesting and challenging. As an illustration, constructors contract to deliver a project to an owner within a prescribed time and for a given price based on a set of plans and specifications. In order to remain competitive and to satisfy the demands of the owners, constructors have to become more innovative. Firms who before would not try anything different are now exploring and implementing new technologies in every aspect of their business so as to remain competitive. Further, with trade barriers between countries effectively reduced and in some instances nonexistent, we find that firms are now forming alliances with owners, suppliers, constructors and designers in different countries so as to have a competitive edge in the market place.

The recognition of these global changes in the industry is the reason why this volume on Innovation, Globalization and Competitiveness is timely. Firms who fail to incorporate innovations in their business will continue to struggle and may eventually go bankrupt. Only firms who have strong leadership in construction business processes will remain profitable and viable.

Globalization has made it possible for firms who previously would not venture outside their country to now seek opportunities elsewhere. Distance is not the issue that it once was. With improvements in information technology, both in hardware and software, collaborations between firms in different countries are now common. This technology is vital for the management of the many pieces of information needed to complete a project. It is particularly effective in construction because projects are complex and require input from designers, and suppliers who may be from different countries. We have not begun to take full advantage of globalization and innovation in the construction industry. In developing countries, there is an acute need for infrastructure to help them develop their economies, while in developed countries, the infrastructure is in need of rehabilitation and renovation. It is argued that Globalization will help to improve the quality of the built environment and provide owners of construction projects with the opportunity to work with those firms that provide the best value, regardless of their physical location.

FOREWORD: Volume 2

Project Delivery Systems, Quality and Workfoce

In the construction industry in the United Sates, and very likely in other countries, there has been a continuous change in project delivery systems in response to increasing owner requirements, fast track scheduling, concern for cost over runs and the high cost of litigation. In the United States, in the 70's, the move was to use professional construction managers (CM) in the construction process. The view at that time was that with construction managers representing the owners, there would be a decline in litigation and in cost and schedule overruns. However, with the evolution of this delivery system, firms started developing hybrids by assuming risks in performing certain aspects of the contract. The initial thought was that if the traditional lump sum general contracting system were corrected, the adversarial relations (between constructors and owners or constructors and designers) that plagued the industry would be solved. Regrettably, the problem in the industry was not just changing the project delivery system. It required a change in culture, value and relationships.

In the agency construction management system, the construction firm assumes the role of an agent to the owner in a relationship parallel to that of the designer and mainly administers work by other construction firms. In the at-risk construction management system, the qualified construction firm is also the constructor of the project, acting much like a general contractor during the construction phase. In at-risk construction management the construction firm assumes the role of an agent for pre-construction services. At some point, prior to the start of construction, that firm assumes the risk of delivering the project at a given price. The at-risk construction manager holds contracts with other trade sub-contractors and may or may not self perform work. However, the at-risk construction manager is responsible for the means and methods for delivery of the completed work. Owners of construction now expect constructors to assure them of quality projects and safe construction sites and to have a qualified and trained workforce on their projects. Indeed, in some instances, firms are evaluated and selected based on how well they score on some of these factors.

Regrettably, the industry is faced with shortages of workers who even when available may not be well trained. Further, the industry is plagued with a negative image with the consequent result that there are fewer new entrants into the workforce. The ability of the industry to meet the needs of the economy lies in its ability to develop innovative project delivery systems and to find ways to attract and train more workers. What is obvious is that the industry cannot maintain the status quo and must, of necessity, explore and implement new strategies in its operations.

INTRODUCTION: Volume 1

Innovation, Globalization and Competitiveness in the Construction Industry is concerned with three themes:

Innovation in the Construction Industry
Globalization & Competitiveness
E-Commerce & the Construction Process

Papers under the theme Innovation in the Construction Industry range from business improvement to innovation to the impact of innovation on the built environment. Thus, these papers provide a broad and yet in-depth view of innovation in the industry. The papers have been purposely arranged to end with the value of innovation to the owner, the primary user of the built environment.

Globalization and Competitiveness starts with the core issues that influence globalization and ends with its impact in some countries. The range of topics covered in this section provides a broad and yet coherent reading of the complexity of globalization.

The third section deals with E-Commerce and the Construction Process. The influence of e-commerce on the global economy is common in most of the papers. This section ends with a presentation that demonstrates the potential of e-commerce.

The Structure of the Volume

In order to better organize the topics in this symposium, the papers have been arranged in two volumes. Each volume focuses on three themes. Volume One covers Innovation in the Construction Industry, Globalization and Competitiveness, and E-Commerce and the Construction Process.

Volume Two covers Innovative Project Delivery Systems, Quality Improvement and Safety in Construction, and Construction Workforce Issues. This arrangement was chosen to make it easier for the reader and also to maintain some consistency within each theme.

Standard

There is now a demand for papers published and presented in a symposium of this nature to be of quality similar to referred journals. For this Symposium, 190 abstracts were received and 150 accepted. The authors of the accepted abstracts were then invited to submit full papers. Of the full papers submitted, 115 were accepted and the authors were asked to incorporate the comments and suggestions from the reviewers in their final draft. Each paper was thoroughly checked by three reviewers. The standard achieved in the review process insures that the papers meet the standard expected in referred journals.

Acknowledgments

We would like to take this opportunity to thank all members of the organizing committee for their valuable contributions. Also we would like to extend special thanks to the staff of the University Conferencing Center and in particular, Ms. Diane Henderson and Ms. Jamie Moser for their assistance in working with the publishers. Thanks are also due to the CRC Editorial staff for their assistance in publishing the papers for "The 10th International Symposium of the W65 Commission on Organization and Management of Construction."

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INTRODUCTION: Volume 2

Project Delivery System, Quality and Workforce are concerned with these themes.

Innovative Project Delivery Systems

Quality Improvement and Safety in Construction

Construction Workforce Issues

The papers under the theme Innovative Project Delivery Systems cover topics from innovative contractual relationships between contractors and subcontractors to a comparative analysis of procurement systems between countries. These papers provide insights into the efforts and creativity employed by the stake holders in trying to develop delivery systems that best meet their needs.

Quality Improvement and Safety in Construction covers topics from safety of construction work zones to the development of a national system of certifying competent construction enterprises. The papers in this section are particularly timely as they present issues that are relevant to providing quality in construction projects.

The section on Workforce Issues starts with the principles that are necessary for effective workforce management and moves to the impact of HIV/AIDS in the construction industry. Virtually all countries have workforce concerns. In the developing countries, there is a large pool of untrained workers, while in the developed countries, there is a shortage of qualified workers. The topics in this section address the need for the industry to focus on construction worker productivity.

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Theme 1: Innovation in the Construction Industry

Business Improvement through Innovation in Construction Firms: The 'Excellence' Approach

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ABSTRACT
Major construction industry review reports as well as recent initiatives such as the Construction Best Practice Programme in the United Kingdom (UK) have identified performance improvement as a key issue. There is now a realization that business performance should not only be based on short-term financial measures but on a comprehensive range of measures incorporating long term objectives as well. The Excellence Model, developed by the European Foundation for Quality Management (EFQM) is an alternative, increasingly seen as a more robust approach for achieving a balanced performance, and for identifying the drivers of innovation in order to sustain long term strategic objectives. This paper addresses the key issues involved in the implementation of the EFQM Model and concludes with an outline of how the model can be used as an innovative tool to develop a recommended strategy for performance improvement.

INTRODUCTION

Major construction industry review reports and recent initiatives such as the Construction Best Practice Programme (CBBP) and Construction Productivity Network (CPN) in the United Kingdom have identified a number of improvement themes. Traditional approaches for measuring improvement are often backward-looking and financially driven, usually resulting in short-term benefits. There is now a realization that performance should be based on a comprehensive range of

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measures reflecting short and long-term objectives of organisations. The Excellence Model, developed by the European Foundation for Quality Management (EFQM, 1999c) is increasingly seen as a robust approach for achieving a balanced business performance. However, the role of the model in facilitating innovation and learning in organisations has not been addressed.

This paper presents the concept of the 'Excellence' approach, demonstrating how the Excellence Model can facilitate the development of an improvement plan underpinned by an innovation strategy to support continuous business improvement. It starts with a brief review of the drive for business improvement, which is followed by a discussion on the use and the barriers in implementing business performance measurement models based on the experience of large construction organisations in the United Kingdom. The issues and stages in the implementation of the Excellence Model are then addressed from the operationalization of the concepts of 'Excellence' to the identification of performance gaps and improvement opportunities. The paper concludes with an outline of how the model can be used as a planning tool to develop an innovation strategy as an integral part of a continuous performance improvement plan.

RESEARCH METHODOLOGY

This study is part of an ongoing research project investigating the relationship between knowledge management and business performance. A variety of research methods are used including literature review, questionnaire survey and semi-structured interviews. The literature review identified the key aspects and issues in performance measurement models. The questionnaire survey identified the types of business performance measurement models used in large construction organisations, highlighting factors that could hinder the successful implementation of performance measurement models. In- depth semi-structured interviews with senior managers and directors in selected construction organisations provided detailed information on the implementation aspects of the Excellence Model.

THE DRIVE FOR BUSINESS PERFORMANCE IMPROVEMENT

Performance improvement has been the subject of recent initiatives in the construction industry in United Kingdom. Pressure for change appears to be increasing also in the construction industry as a result of complex factors including changes in the market conditions and client expectations. The drive for continuous improvement is therefore gaining momentum, as construction organisations are not only expected to deliver projects within a given time and budget but also to a high quality by increasingly demanding clients.

Performance Improvement and Organisational Strategy

There are two elements to a performance system. Firstly, the performance issues need to be identified i.e. to translate what needs to be improved to performance indicators, and secondly, the performance issues should be measurable. Quality does not improve unless it is measured (Reicheld and Sasser, 1990), and 'what gets measured gets attention, particularly when rewards are tied to the measures' (Eccles, 1991). Approaches for improving business performance have evolved over the years from simple quality inspection to total quality management and investors in people. However, these approaches often separate quality principles from the results, hence most business improvement initiatives have failed to achieve their desired impact because of the lack of an explicit connection between quality principles and results. This is often due to a narrow interpretation of quality issues. Quality is not simply a problem to be solved, it is also a competitive opportunity (Gavin, 1987), and should therefore be an integral part of strategic management.

Strategic management has traditionally been divided into two distinct aspects. The economic aspect typically deals with the formulation of strategy (industry and competitive analysis) whilst the management aspect largely deals with the implementation of strategy such as structure, measurement and reward system, as well as resource allocation. However, Leavy (1996) argued that new emphasis has emerged shifting the centre of gravity from external industry organisation and market structure to internal processes and competencies. This means that organisational capability i.e. the ability of organisations to improve business processes and increase competencies through innovation and learning, is now central to securing competitive advantage. Measurement is also becoming increasingly important as an integral part of performance improvement but it is often the financial aspects that are measured.

The Need for Comprehensive Performance Measurement

The dominance of financial aspects in performance measurement is largely driven by practices in traditional accounting systems with a disproportionate emphasis on short term indicators such as cash flow, profit, return on capital employed, turnover and quarterly earnings (Whiting, 1986). However, reliance on financial indicators as key performance measures can, at best, result in short term benefits. This point is also illustrated by Sommerville and Robertson (2000) who argued that 'an organisation adopting the principles of Total Quality Management (TQM) quickly appreciates that financial measures on their own are very limited in reflecting the wider aspects of achievements and progress in general'. This narrow measurement approach is often at the expense of understanding the key connections to process, product and people measures that influence financial performance. Such short-sightedness can have adverse effects on the long-term competitive opportunities, as organisations with limited performance-based approaches tend to pay less attention to other crucial aspects of their business.

Measurement of people, product and process performance in business is therefore essential in identifying areas for improvement. However, most businesses lack rigorous performance measures for their processes (Hammer and Stanton, 1999). The need for comprehensive performance measurement approaches has recently led to the development of key performance indicators (KPIs) for construction in the United Kingdom. The purpose of KPIs is to enable measurement of project and organisational performance throughout the construction industry, and for organisations to benchmark towards achieving best practice (Department of the Environment, Transport and the Regions, 2000). Other approaches include Hoxley's (2000) 26-item scale for assessing quality in construction professional service organisations. Sinthawanarong (2000) also developed a methodology using indicators reflecting cost, time, safety and quality factors as the most crucial variables determining construction project performance. Although these approaches are specific to the construction industry, they reflect a growing trend in the wider business context that performance should be treated as a multi-dimensional measure. Construction organisations are beginning to focus on a range of quality measures reflecting product issues (e.g. defect rates, client satisfaction, society view), process issues (e.g. safety, procurement) and people issues (e.g. employee satisfaction and involvement) to facilitate business improvement. As a result, some construction organisations are now implementing various types of business performance measurement models, and their experience of using such models are discussed in the next section.

THE 'EXCELLENCE' APPROACH

The Excellence Model introduced by the European Foundation for Quality Management is a universal model developed to encourage organisations to adopt a forward-looking approach by focusing on a broad range of measures reflecting the wider business environment. The EFQM was created in 1988 by fourteen leading European businesses as a not-for-profit organisation 'to promote an approach to management for all organisations operating in Europe that would lead to Sustainable Excellence'. The membership is now well over 750 organisations from most European countries reflecting most sectors of activities/ industries in the private and public sectors. The Excellence Model incorporates measures for leadership, processes, policy and strategy, people and society issues to assess performance. It is, therefore, increasingly seen as a more robust approach for achieving a balanced performance. Also, it provides an explicit approach for identifying the drivers of innovation and learning to create and sustain competitive advantage. Although the Excellence Model has been around for 10 years, it has only recently been taken up in construction organisations. However, it is expected that more organisations within the construction sector will adopt it as the implementation barriers are gradually being overcome and the business benefits of using it becomes increasingly clear.

The Experience of Large Construction Organisations

A growing number of construction organisations are now adopting a performance measurement and improvement model reflecting the need to improve their business performance by focusing on wider business performance issues. A recent survey shows that over a third are using either the Balanced Scorecard (BSC) or the Excellence Model (EM) with a higher proportion using the Excellence Model (22.6%) than the Balanced Scorecard (13.2%). About 11.3% are using both the BSC and EM. A quarter (26.4%) are using other measurement systems, mainly the Egan KPIs, related approaches or bespoke models. The rest (22.6 %) do not use any performance measurement system. Although the Excellence Model and Balanced Scorecard has been around for over 10 years, they have only been taken up recently in construction organisations. The survey shows that both models have been in use for the same period ranging from 6 months to 6 years. But on average the Excellence Model has been in use for a slightly longer period (2.75 years) than the Balanced Scorecard (2.60 years). About 43.9% of the organisations have adopted the EM as a performance measurement and improvement tool for at least 3 years compared to 45.5% for the BSC. In terms of the business benefits of using performance measurement models, 17.4% rated the Excellence Model as very good, 43.5% good, and the rest (39.1%) were unsure. The corresponding figures for the BSC are 21.1% (very good), 42.1% (good) and 36.8% unsure. About 57.1% rated the KPI, related approaches or bespoke models as good, 28.6% are unsure and the rest rated them as poor. None of the organisations rated the EM or the BSC as poor or very poor. The slightly higher overall rating for BSC probably reflects the view that the BSC is often considered simpler and easier to use and understand.

However, there were some concerns about the implementation of the models. Difficulties in determining and monitoring indicators and data were identified as the most significant barriers. In-depth semi-structured interviews with large construction organisations reveal that they are already using some key performance indicators (KPIs) such as construction time, construction cost, defects, client satisfaction, profitability, productivity and safety. These KPIs are often project-related measures rather than corporate. Also, the measures are often lagging reflecting past performance. Some organisations recognise the limitations of lagging measures and are now making attempts to incorporate leading measures in their business performance measurement models. Problems associated with determining and monitoring indicators include choosing the wrong measures and not aligning measures to organisational strategy. Data collection is also a key problem as most construction organisations are at the infancy stages of implementation. It is also difficult to compare KPIs because of the difficulties involved in data gathering and lack of standardization. Financial resources to implement the models have also been cited as a barrier given the low profit margins, and low investment in research & development often associated with construction organisations. Some also argue that implementation takes a lot of time requiring significant changes in personnel and resource allocation. Figure 1 is a comparison of the barriers identified with respect to two different types of business performance measurement models - the Excellence Model and the Balanced Scorecard. A five-point rating scale is used ranging from the least significant (1) to the most significant (5).

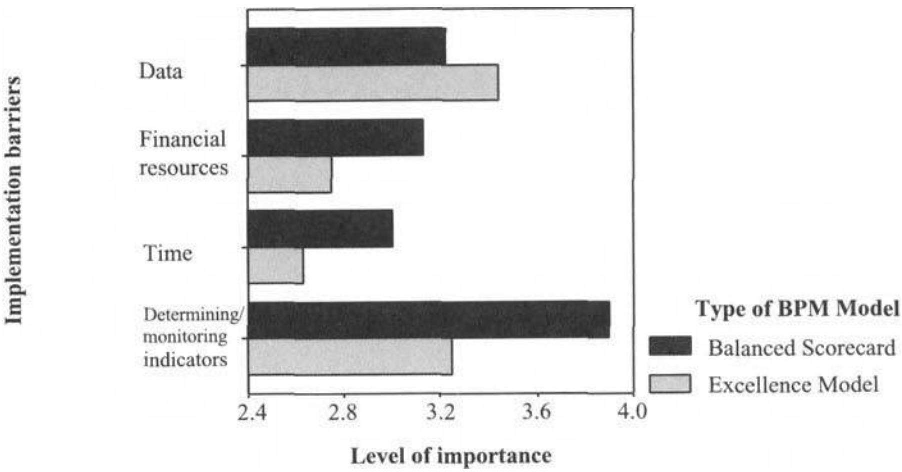

Figure 1 Barriers in the implementation of the Excellence Model and the Balanced Scorecard

Other problems highlighted include excessive emphasis on scoring, insufficient emphasis on continuous improvement and difficulties in understanding the model.

THE CONCEPTS OF 'EXCELLENCE'

Excellence is defined 'as outstanding practice in managing the organisation and achieving results' (EFQM, 1999b). It is underpinned by eight fundamental concepts shown in Figure 2. The successful implementation of the 'Excellence' approach depends on the application of eight fundamental concepts as follows:

- Customers' needs are to be clearly understood;
- A strong leadership is required providing clarity in the organisation;

- Processes must be owned, managed properly and regularly improved;
- People must be empowered and encouraged to fully participate in the organisation;
- Continuous learning and innovation should be the lifeblood of the organisation;
- Partnerships should be developed based on mutual benefit and trust;
- A public oriented approach reflecting the concerns and aspirations of society is essential in the delivery of services; and
- Consideration of all stakeholders involved will lead to excellent results.

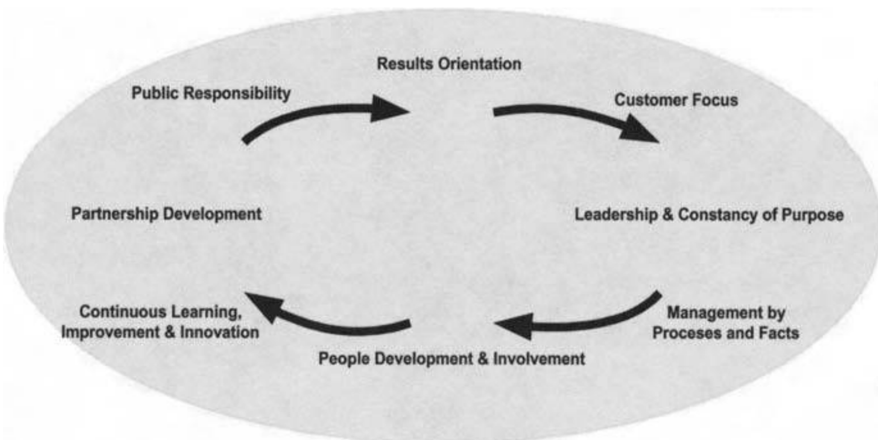

Figure 2 Fundamental concepts of 'Excellence'. Source: EFQM (1999b)

The five key drivers identified by Egan (1998) for a radical change in the construction industry are all incorporated in one form or another in the 'excellence' concepts. Adopting each of these concepts provides significant benefits to organisations including organisational agility, cost reduction, opportunity identification, and performance optimisation (EFQM, 1999b). For example, the customer focus concept means that the customer 'is the final arbiter of goods and service quality, and market share is best optimised through a clear focus on the needs and requirements of current and potential customers'. Significant benefits to be gained from a customer-focus approach include increased market share, minimisation of transaction costs, a clear understanding of how to deliver value to the customer and long term success.

Several stages are required in the implementation of the 'Excellence' approach. These stages are discussed in the subsequent sections.

Operationalization of the Concepts of 'Excellence'

The first stage involves incorporating the eight fundamental concepts into an organisation's business plan. This is achieved by adopting the Excellence Model as a strategic tool in the business plan with criteria reflecting the enablers and results of an organisation as well as showing the links between the enablers, results and innovation and learning components (see Figure 3). The Excellence approach encourages organisations to concentrate on actions needed to achieve an all round excellent performance rather than concentrating on financial performance only. There are five enabling criteria; leadership, policy and strategy, people, partnerships and resources and processes.

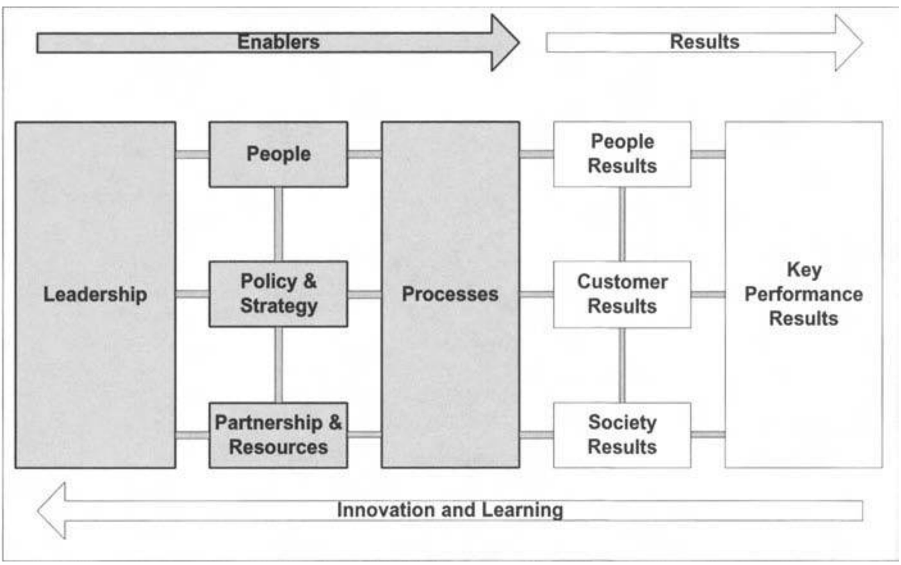

Figure 3 The Excellence Model. Source: EFQM, 1999a

Identification of the Requirements of the Business Plan

The second stage involves asking a series of questions to identify gaps in the implementation of an organisation's business plan and to determine the responses required. Examples of the questions include: are the goals/mission and vision statements in the business plan adequately translated into policy and strategy? what are the processes required for the delivery of goods and services? are the people in the organisation capable of implementing the policies and strategies? are the partnership and resources available to support the processes? what leadership is needed to achieve the required results?

Development of Performance Measures

The third stage is about determining appropriate measures to reflect the enabler criteria, so that performance can be measured and monitored. Each of these enablers has its own sub-criteria reflecting the goals of the organisation. Examples of sub-criteria and measures are shown in Table 1.

Table 1 Examples of selected measures

Criteria	Sub-criteria/ Measures	Metric Definition	Data Source	Reporting Frequency
Leadership	• leadership potential index • leadership clarity index	• %age of staff with leadership potential • %age of staff understanding direction of organisation	• internal survey • internal survey	monthly monthly
People	• staff turnover • customer satisfaction index • public perception	• %age of staff leaving • nos. of customer complaints • nos. of press complaints	• personnel report • customer questionnaire • newspapers	monthly monthly weekly
Policy and strategy	• business objectives and plan	• %age of staff meeting business objectives and targets	• strategic plan	annually
Partnership & resources	• suppliers perception • revenue from partnership	• nos. of complaints from suppliers • revenue per head of employee	• supplier survey • project report	monthly annually
Processes	• improved processes • health and safety record • bid/win ratio	• nos. of new ideas implemented • nos. of accidents • nos. of bids won out of total submitted tenders	• business improvement report • safety report • tender report	quarterly monthly monthly

These sub-criteria and measures could also reflect the objectives at different levels of an organisation - departmental, functional, corporate or project level. As the Excellence Model is robust, different measures and weightings could also be used to reflect the strategic objectives or priorities of an organisation. For example, if the strategic objective of the organisation is to expand, measures such as bid/win ratio and workload could be given higher significance. If, on the other hand, the strategic objective is to maximise stakeholders' involvement, then measures such as staff turnover, customer satisfaction index and public perception could be given significant weightings.

Assessment of Results

The fourth stage is assessing the results. The enablers provide the results - in terms of customer, people, society and key performance results reflecting the organisation's financial and non-financial outcomes. The results are assessed by a range of techniques from opinion -based perception measurement to highly structured evidence-based approaches for measuring and monitoring changes in performance scores/ indicators determined from various sources. Assessment can be carried out by external assessors, externally trained internal assessors using a range of inputs such as facilitated workshops, questionnaires sent to staff, customers and suppliers.

The results are assessed on trends, targets, comparisons, scope and benchmarked against other organisations. Scoring is usually from 0 to 100%. But there is also the alternative Pathfinder Card, which is a useful tool for organisations that chooses not to score. Its purpose is simply to help identify improvement opportunities and build improvement plans. It is achieved by asking a series of questions that can be answered quickly while doing the self-assessment. The concepts illustrate that the evidence for achieving excellent results is underpinned by a range of measures called enablers. Excellence is therefore not just limited to financial results demonstrating the outcome of past performance but also includes evidence from other stakeholders that serve as leading indicators for future financial performance. These leading indicators include measures for customer satisfaction, people (employee) satisfaction and society view. However, customer, people and society results are in turn driven by enablers - processes supported by leadership styles, the existence of a clear policy and strategy, partnership and resources in the delivery of goods and services (products).

Evaluation and Identification of Improvement Opportunities

The fifth stage involves evaluating the results, identifying improvement opportunities and assessing the implications for innovation and learning. The results are evaluated using the RADAR (**R**esults, **A**pproach, **D**eployment, **A**ssessment and **R**eview) logic.

The RADAR logic means that organisations' need to:

- determine the **R**esults it wishes to achieve
- plan and develop the **A**pproaches it is to use

- systematically Deploy those approaches
- Assess and Review the approaches and then prioritise, plan and implement improvement

The improvement plan will focus on gaps identified, and some of the activities will also have a knowledge and innovation dimension. The Excellence Model therefore provides the basis for organisations to move away from reactive (backward-looking) to proactive (forward-looking) or innovative indicators.

DEVELOPMENT OF AN IMPROVEMENT PLAN

Recent changes in the UK construction industry such as partnering, supply chain management and increased awareness of the benefits of process mapping are a reflection of the growing need to innovate and to improve performance. The Excellence Model recognises that the innovative and learning capacity is one of the key factors for organisational excellence, as it is connected through a feedback process to the results achieved. This explicit connection signifies the importance of innovation and encourages learning in improving results. Organisational performance is maximised when it is based on the management and sharing of knowledge within a culture of innovation which then leads to continuous improvement. There are several types of innovation; systems, breakthrough and incremental (Marquis, 1988; Abernathy and Utterback, 1988). Systems or radical innovation are characterised by major discoveries that can change the whole character of an industry. Breakthrough innovation deals with significant changes but of a lesser scale. The third type - incremental or evolutionary innovation - deals with the 'ordinary, everyday, within-the-firm kind of technological change without which industrial firms can, and do, perish' (Marquis, 1988).

Towards an Innovation Strategy

The Excellence Model provides a coherent framework for measuring the 'innovativeness' or innovation capacity of organisations, particularly the incremental (evolutionary) type of innovation required for continuous business improvement. A number of indicators could be developed for the improvement plan as part of an innovation strategy to reflect the degree of innovativeness or the innovation potential of an organisation. These indicators could reflect the different components of the model as well as the types of innovation from incremental (evolutionary) to systems (revolutionary) innovation. For example, measures could be introduced for the number of new ideas converted into business ventures, revenue from new business partnerships, new business processes identified, proportion of staff rated as innovative and number of knowledge and innovation champions. Innovative potential of leaders is absolutely crucial as 'continuous innovation occurs largely because a few key executives have a broad vision of what their organisations can accomplish for the world and lead their enterprises towards it' (Quinn, 1988). Such visions are important to attract and retain quality people as well as to nurture their innovative and creative drives. Kono (1984) also emphasised the importance of innovative management to project clear long term visions for their organisations that go beyond simple economic performance measurements. The Excellence Model is a framework that facilitates innovative management as it recognises that excellent organisations should look beyond simple economic performance measurements.

Innovation Phases

Innovation is a set of processes that evolves from the recognition of a need to the utilisation and diffusion of a product (goods/ services) arising from that need. Table 2 shows the phases involved in innovation.

Table 2 Innovation Phases. Source: compiled from Marquis (1988)

Innovation Phase	Activities
Need recognition	Identification of a new idea which involves the recognition of both technical feasibility and demand
Idea formulation	Fusion of a recognised demand and a recognised technical feasibility into a design concept
Problem solving	Gathering of information at hand and exploring through R and D where information is not available
Solution	Verification of the technical feasibility and demand which were originally recognised
Development	Resolving uncertainties with respect to market demand and the problems of scaling up production
Utilisation and diffusion	Testing the demand for the products to achieve sales, profits and returns on investment

Marquis (1988) argued that small incremental innovations contribute significantly to commercial success, and the recognition of demand is a more frequent factor in successful innovation than technical potential. The Excellence Model facilitates incremental innovation as it identifies gaps and continuous improvement opportunities. It is also demand driven i.e. customers are recognised as central to business activities. Quinn (1988) noted that most innovative enterprises 'consciously tap into multiple outside sources of technological capability, and the first of these is their own customers'. The growth of Private Finance Initiatives (PFI), Public Private Partnerships (PPP) or Service Delivery systems in the UK construction sector is also in response to this customer-centred approach (Corley *et al*, 2001).

The interaction with suppliers and other partnerships, sometimes in completely unrelated industries also provides a rich source of innovative ideas, in which totally new concepts and opportunities are created. The increasing reliance on supply chain management and partnering in the construction industry is a clear indication of the importance attached to interacting with suppliers and other partnerships in order to continuously improve business performance.

Some large construction organisations are now redefining their strategies, as partnerships, customer and society views are becoming increasingly important in the delivery of products (services/goods). Organisations now recognise that a customer-driven approach through feedback from satisfied as well as disaffected customers can direct attention to key issues and help develop vital customer capital to continuously improve performance (McColl-Kennedy and Schneider, 2000). Constant product feedback through better targeting of customers can drive changes in processes which in turn can stimulate process actors (people) to become more active in learning, sharing knowledge of best practice, and searching for new knowledge, ideas and innovative approaches. Table 3 shows the different maturity stages for innovation using the 'Excellence' approach.

Organisations at the start-up stage will be characterised by the identification of improvement opportunities, which will be acted upon only by a selection of key staff. At the maturity stage, organisations will become regularly involved in innovation, as improvement activities become part of the organisation's culture. A key factor in the drive for innovation is the identification of a 'knowledge and innovation champion' - a crucial mechanism for the sharing and transferring of knowledge in construction organisations (Egbu, 2000). Research and development capability is also an important factor. Gann (2001) argued that research and development capability of construction organisations need to be improved to be able to absorb and apply the results of research for industrial use. However, the low investment in R & D, which has fallen by 80% since 1981, is damaging the industry's ability to keep abreast of innovation in processes and technology (Egan, 1998). The 'Excellence' approach will encourage organisations to continuously search for incremental improvement opportunities, and in the process innovative solutions can be identified which can lead to new ways of delivering products.

Table 3 Innovation maturity stages. Source (EFQM, 1999)

Innovation Status	Characteristics
Start up stage	improvement opportunities are identified and acted on
On-the-way stage	continuous improvement is an accepted objective for every individual
Mature stage	successful innovation and improvement is widespread and integrated

CONCLUSION

Business improvement is vital for construction organisations but there is a need for a sustained approach recognising that incremental innovation is central to continuous improvement. The 'Excellence' approach has been presented as a framework that provides an explicit link between organisational results and innovation and learning to support continuous performance improvement. The key stages in the implementation of the Excellence Model from the operationalization of the concepts to the identification of improvement opportunities are discussed. The development of an improvement plan is also outlined as the basis for implementing innovation strategies that are not only aligned to business performance measures but also consistent with the overall business goals and strategic objectives. Knowledge management is vital for innovation and as part of an on-going research project, the 'Excellence' model is being explored as a tool to facilitate the introduction and assessment of knowledge management initiatives necessary to drive innovation for continuous business improvement. Further development of the role of innovation using the 'Excellence' approach is being addressed through a project examining the relationship between knowledge management and business performance.

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A Theoretical Framework for Understanding Construction Innovation: An Organizational Perspective

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ABSTRACT

A theoretical framework is developed to capture innovation processes in construction projects. Different stakeholder organizations are divided into two major interest groups while planning and implementing innovation in a project. The external, inter and intra-organizational pressures that the groups face are presented in a generic form in the framework. The wide-ranging dynamic picture would help depict the spectrum of interrelated problem areas in fostering innovation in construction projects. The identification and analysis of these problem areas would enable the development of effective guide to design effective solutions. Such solutions would be key to stimulating innovation in the construction industry.

Key words: INNOVATION, CONSTRUCTION PROJECT ORGANIZATIONS, PROBLEM AREAS, COMPREHENSIVE FRAMEWORK

INTRODUCTION

Despite of the general understanding that innovation is an effective entry point concept to step up productivity and economic advantages, there are wide ranges of internal and external hindrances in construction industry that thwart the attempts and processes of the concept itself. The internal barriers include rigid organizational structures; resource scarcity; embedded non-resilient attitude, values, working culture and resulting resource allocation decisions, and the external ones include adverse institutional and regulatory framework and perceived market conditions (Tatum, 1984, 1986; Nam and Tatum, 1989; Gerwick, 1998; Markides, 1998). Further, the mutual interactions of these two sets of barriers are the general causes of skepticism and reluctance in implementation of innovation. A deeper query in construction sector revealed that these barriers crop up due to more subtle reasons emanating from the tacit institutional set-up and resulting organizational behavior patterns.

Unlike other products, final construction products essentially demand coordinated efforts from all the stakeholders' in the supply chain within a limited time frame of project duration. Inter organizational coordination of different specialized organizations is a challenge in construction production process. Close information and resource exchange between the organizations which is one of the prerequisites of innovation determination and implementation is yet another challenge. The separate specialized organizations jointly working for one single project may not be motivated for thinking, determining and implementing innovation in that particular project; rather, most likely they would be more concentrated in completing the project to fulfill their individual interests. Tatum (1986) and Winch (1998), thus state that fragmentation in construction makes the innovation more difficult than in other industries. There is more subtle challenge of integration of the organizations on the ground of alignment of their fragmented motivation.

This paper presents a theoretical framework that attempts to capture how the organizations are interrelated and expected to behave when there is a process of innovation in a construction project. The framework would be useful to trace the problems and causes, of construction innovation process in a project, which could serve as an initial step to design effective solutions. Construction project participants who are planning to introduce innovation in their projects would find this paper useful and instructive.

THE PROBABLE SOLUTION

The General Observation

The manufacturing sector, though not free of problems, is ahead of construction sector in innovation implementation (Lenard, 2001). Construction sector is lagged behind the demand of customers while manufacturing sector, in general, is found to be successful in preceding customer demand by introducing alluring innovative ideas and products. The unique research and development (R&D) function focusing on concerted effort in innovation and functionally integrated with other organizational units has been identified as the key of the success in widespread innovation in the Japanese manufacturing firms (Wakasugi, 1992). Likewise the success of Japanese automobile industries is attributed to long-term management commitment (Cusumano, 1988). Quinn (1985) elucidates crucial factors to the success of innovative small companies as, need orientation, experts and fanatics, long time horizons, low early costs, multiple approaches, flexibility and quickness, incentives and availability of capital. For the large companies, success factors include top-level understanding, vision, a commitment to customers and solutions, a genuine portfolio strategy, a flexible entrepreneurial atmosphere, and proper incentives for innovative champions. Quinn (1985) further indicates that the innovative process is inherently incremental and probabilistic. Major innovations are best managed as incremental, goal-oriented, interactive learning processes and only highly committed entrepreneurs can tolerate such innovation chaos. Drucker (1985) also emphasizes on committed systematic innovation to manage the paradox of choosing one of the alternatives, of continuing regular and certain business, or going together with disorderly unpredictable innovation process. Markides (1998) gives clues for strategic innovation in terms of the challenge in dismantling status quo attitude in organization for periodic rejuvenation. He explains that ups and downs are bound to prevail, but a strategy should be formulated during the peaks of ups so that rejuvenation can be realized in one way or the other. As the strategic innovation will be different from the status quo, he emphasizes the need for separate institutional support for formulation and implementation of strategic innovation.

Tatum (1989) explored some opportunities for innovation in the construction sector out of its unfavorable set-up. He illustrates that the necessity of specific projects, the opportunity for design-construction integration, process emphasis, variation in methods, and the capability and experience of personnel offer some significant advantage for innovation in construction as compared with other industries. In order to foster these opportunities, he points out that the organizational structure, culture, supportive policies and priorities, flexibility in unit size and grouping, intra and inter organizational coordination, and staffing to satisfy specific requirement for key positions, are the key elements. He elaborates the supportive policy for innovation in construction firm as long-term viewpoint, broader view of risk, implicit vertical integration, importance of planning and innovation culture itself. Gerwick (1998) explains that innovation requires both the receptive and accommodating environment along with sound management system. He asserts that in order to generate motivation towards innovation, it should be ensured that contracting and management procedures enable the realization of economical and profitable results from the utilization of the innovation.

Nam and Tatum (1992) divide the factors that induce construction innovation into two sides: demand side (owner and market) and supply side (available technology). They observed that in most successful processes of construction innovation, technology plays a critical role in inducing the owner’s demand as well as in formulating problems, and the owner’s mindset is one of the factors that enables or inhibits innovation in construction. So they deduce that progressive owner and formal R&D effort for technology development are the important factors that increase size and rate of innovation.

The Favorable Approach

Review of current knowledge has identified different threads of contributions, in the field of innovation in manufacturing and in construction sector, which can be summarized into two basic categories. First, based on logical deductions or case studies, a list of factors that affect innovation are prescribed in most of the literature. Second, as long term measures, there is emphasis on integrated R&D activities and separate sub-organization to deal with organizational innovation needs and implementation strategies. However, a comprehensive framework to capture the whole innovation processes in the construction sector is still missing (Tatum, 1986). As construction is a complex system industry (Nam and Tatum, 1988; Winch, 1998), the tool or thinking paradigm needed to comprehend the whole innovation processes in construction might be different from the mere prescriptive guidelines.

Prior to proceeding for finer analysis, it is necessary to work out a thinking paradigm and an effective framework that serve as foundation and structure for a research agenda. The nature of the problem in construction innovation is an inter-organizational as well as intra-organizational problem, with multiple arrays of the stakeholders and their aligning and conflicting interest variables. It is a high order system problem. The relationship between the variables in the system is not obvious and straightforward, the short-term solution does not work for the long term and the long-term solution is painfully unacceptable in the short run; the problem is a highly non-linear system problem (Van de Ven et al., 1999). There are multiple feedback relationships between the variables indicating the multitudes of interdependency. The time delay between action and corresponding consequence is difficult to conceive and appreciate. These very characteristics of high order, non-linear, multiple feedback and time delay (Forrester, 1961) make the process of innovation implementation in the organizational set-up (Gross et al., 1971, pp. 30-31) of construction sector highly dynamic and complex. Such a complex problem demands a holistic vision for a probable higher leverage solution set (Senge, 1990; Gerwick, 1998).

THEORETICAL FRAMEWORK

A holistic framework has been prepared referring simulation models developed by Sterman et al. (1997) and Repenning (2001). They basically prepared dynamic models for the manufacturing sector which address the problems of innovation implementation. The dynamic concept of generation of innovative attitude, commitment and their behavioral consequences are captured and adapted in the case of construction project scenario.

The main concept behind this new framework is to capture innovation dynamics within a whole construction project organization. It is an aggregated generic framework and can be applied to capture a possible spectrum of different construction innovation cases. The concept of motivation alignment, integration and their influence on the innovation is implicitly incorporated in the framework.

In order to generalize a project organization which is implementing an innovative idea, it is divided into two major blocks. One is the stakeholder organization in a project that comes up with the innovative idea and proposes it. This stakeholder organization is termed as "Origin Organization" (OO), implying the origin of innovation. The other block is all the relevant stakeholders in the project whose support is needed for the OO in order to implement the proposed innovation. This supporting block of organizations is termed as "Supporting Organizations" (SOs). A detailed discussion of the theoretical framework, depicted in Figure 1, is presented below.

Pre-Implementation Phase

The reason why an organization would come up with an innovation is the expected achievement of tacit or explicit goal(s) by implementing the innovation. The OO in a project comes up with innovative idea in order to achieve its intended goal(s). The goal could be conditioned by the perceived external constraints such as project scope, own capability, perceived capability of the other stakeholders and perceived regulatory or legal constraints. OO also need to demonstrate firm commitment in order to achieve its intended goal. A higher level of goal would demand a higher extent of commitment. The more the desired commitment, the wider would be the gap between the prevailing state of commitment and the desired commitment. The perception of the gap or discrepancy is the cause of pressure (Zaltman et al., 1973) for OO's management to work for the stipulated innovative steps. The pressure is translated into a set of standards or norms that should be followed in the OO and works as normative pressure from its management to induce operational commitment at the project level (indicated by the loop L1 in Figure 1).

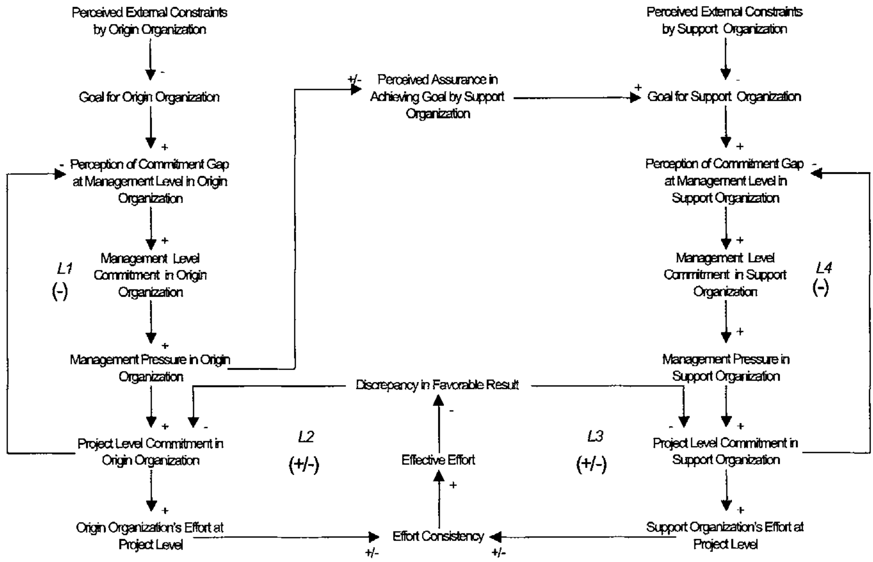

Fig. 1. Framework of Construction Innovation Dynamics

In order to implement the innovation, the OO should coordinate and work with relevant SOs in the project. The SOs are also conditioned by their own sets of different goals and preferences. The goal sets of different SOs could be heterogeneous. When the OO coordinates with the SOs it is hypothesized that the proposal of the new idea would get translated into normative pressure from the former to the latter organization. The strength of pressure however depends on the decision power of the OO in the project and perceived attractiveness of the proposal. The SOs may or may not perceive the innovation proposal as a means to assure their individual goal fulfillment. It depends on the nature of the proposal and perception of the SOs. Thus the perception of the proposal further conditions the goal levels of the SOs. If the SOs are convinced that the proposal would be helpful in fulfilling their goal, they would have distinct management commitment to work for the innovation, which would be translated into normative pressure and operational commitment at their respective organizations (indicated by the loop L4 in Figure 1). If they are not convinced, then their managerial and operational commitment would be feeble; or they might be reluctant in going with the innovation. This commitment trend of the OO and the different SOs is an indication of alignment of motivation at pre-implementation stage.

Implementation Phase

Any innovative idea would get implemented in a construction project only if the OO puts in adequate managerial and operational commitment, and has supportive commitment of the SOs. The commitment to fulfill the goal leads to concerted effort among the different parties. Therefore, the commitment level of the OO and SOs would be translated into their respective effort in implementing the innovation. However, it is necessary in a project organization that the effort of the OO and SOs should be streamlined towards their respective consenting results. The effort of the OO may be streamlined towards their intended goal, but the effort of the SOs may or may not be in the line of the OO's expectancy. There are many factors, like the level of operational commitments, conflict in goal, coordination of the effort, knowledge and information exchange between the OO and SOs, which affect the effort consistency. This concept of consensus and coordination in the effort of the stakeholders towards the consenting result of innovation is termed as effort consistency. It is a surrogate variable to represent the degree of integration in a project organization.

The level of consistency in the effort determines the effectiveness of the effort itself. The more effective the effort, the less would be the discrepancy or disagreement in favorable result for the OO and SOs. The favorable results are directly instrumental in inducing more commitment towards the innovation. Therefore, the less the discrepancy in favorable result, or the more the favorable results for different stakeholders, the more would be their respective commitment level.

The loop (L2 or L3), that contains the commitment-induced effort, the resulting effort consistency, the consequent result judgment and the result-induced commitment in turn, could exhibit two scenarios. First, if the effort is influential in enhancing the overall effort consistency, then the loop would be a reinforcing loop. That means the variables in this loop have potential to reinforce each other. Second, if the effort is not influential in enhancing overall effort consistency, then the loop would be a limiting loop. That means the variables in this loop would have limited potential to reinforce each other. In the first case, there would be high possibility of sustaining the innovation with favorable result if there is adequate operational commitment. However, in the second case, there would not be any possibility of sustaining innovation even with adequate operational commitment. Therefore it is necessary that the OO and SOs exert effort collectively and consistently so that each would get favorable result and consequent enhanced commitment for sustained innovation implementations.

DISCUSSION

Implementation of innovation in a construction project organization is a complex process. First, at the pre-implementation phase, an OO should come up with an innovative idea with a distinct goal and commitment. The expected goal and commitment is highly dependent on the industry environment perceived by the OO.

The OO may be reluctant to take a risk at this very initial phase of innovation implementation. Even if the OO is optimistic with its new idea, it has to coordinate with the other stakeholders in the project organization. These stakeholders possess their own goals, culture, values, influential power, and technical and managerial capability. They may or may not perceive that the new idea would be helpful in achieving their goals so that they can work with commitment. There is a question of alignment of motivation at this stage. Even if the management of the OO and SOs are committed with the new idea, there is challenge in gaining operational commitment in their respective organizations. It takes time and resources to prepare the operational body of each organization to implement the new idea. Even after preparing the operational bodies, there is still a high chance of getting inconsistency in their respective effort, as the construction is highly heterogeneous process with complex localization. Integration and coordination between the OO and SOs is a challenge to harness consistent effort from them. Inconsistent effort would produce unfavorable results that may not be conducive to enhance further commitment and further effort. Even if the results are favorable, as construction is normally a single volume production process, there is less chance that the results would be instrumental in stimulating further implementation of the same innovation. So, these very processes can create hurdles and disincentives for fostering innovation in construction. The decision processes embedded in the framework are conditioned by surrounding perceptions and the action followed by the conditioned decisions affect the surroundings which in turn forces to take further decisions and actions. Clear understanding of these processes would help design effective decision structure to foster innovation in construction.

CONCLUSION

This paper has attempted to a sketch a holistic picture depicting problem areas in innovation in construction. The theoretical framework proposed in this study highlighted various stages of innovation like initialization, attitude formation, initial coordination, operational coordination, and implementation coordination, which are critical for successful implementation of innovation. The stages and decisions taken in each stage affect the working conditions of multiple organizations within the project team as each of them has a different working period and goals. Clear understanding of these causal relationships is crucial in order to design effective decision rules in construction organizations.

This paper however gives only a glimpse of "why" innovation is so difficult to be implemented successfully in construction projects. For the question of "how" effective measures can be developed and tested, further testing and validation of the framework might be necessary.

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Innovation in Construction - The View of the Client

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ABSTRACT

The process of planning and erecting a building only starts if the client has made a decision to build. Building depends on the client, it is production by order. From the beginning on the building is determined by the specific needs of the client. On the one hand constructional problems can originate from these needs, which can only be solved appropriately through innovative ideas. On the other hand new constructional solutions offered by construction companies can lead to a better performance of the building or the building process. In both cases risks arise from the novelty of solutions. Little or no experience in using new construction methods or a lack of knowledge about the long term behaviour of new material can cause the client to refuse the use of an innovation in the building project. Therefore, for construction companies understanding the behaviour of the client concerning innovation is a prerequisite for developing and introducing novelties. This paper presents the results of an investigation, which was carried out by interviews with professional clients. The investigation aimed at determining the importance of innovative constructional solutions for the client, the demands of the client for realizing innovative constructional solutions and the incentives for innovative constructional solutions set by the client. With the findings of the investigation conclusions for the innovative activity of construction companies could be drawn.

INTRODUCTION

At the latest since the beginning of the 1990s the subject of innovation has become important in construction industry, too. A great number of publications show that the interest in innovation processes in construction industry has increased. Up to now most of these contributions do not go beyond reflections on plausibility though, and there is still a lack of empirically based findings. The empirical works have so far focused on examining organisational aspects of innovation processes in construction projects (Slaughter, 1998) and companies (Laborde and Sanvido, 1994) as well as on finding out the influencing factors on the innovative behaviour of the whole branch of industry (Seaden et al., 2000) or specific groups of companies (Barrett et al., 2001). These works often regarded the changed needs of the clients as the reason for the importance and the necessity of innovations. What has not been examined up to now are exactly these needs of the clients or their attitude towards innovations in construction industry as a reaction to their changed needs. This is particularly surprising, because as in no other industry the client in construction industry has a considerable influence both on the constructed facility and on the process of planning and execution (construction process).

The construction process of a constructed facility will only start, if the client has taken the decision to build. Building means manufacturing depending on the client or producing by order. The specific concepts the client has on the usage have to be taken into account from the start of the construction process. On the one hand such concepts can lead to problems that can only be solved properly by innovative ideas. On the other hand new solutions to a problem suggested by the company can help to considerably improve the characteristics of the constructed facility and with this contribute to the fulfilment of its function or the efficiency of the construction process. In both cases a certain risk arises from the novelty of the solution to the problem. Few or no experience at all on how to deal with new construction methods or small knowledge of the long-term behaviour of new materials can serve as examples for reasons that might induce the client to object to the application of innovative constructional solutions in a construction project. Understanding the client's attitude towards innovations is therefore a prerequisite for the successful development and introduction of innovations by companies in the construction industry. This paper is intended to contribute to this understanding by presenting the results of a study on exactly the mentioned attitude of the clients with respect to innovative constructional solutions.

THE CLIENT'S POSITION IN CONSTRUCTION INDUSTRY

One of the peculiarities of the construction industry as compared to the manufacturing industry, which produces goods for an anonymous market, is that in construction industry the production is depending on the client. It is not the construction company that takes the initiative to produce a constructed facility. Normally the construction process only starts, when the client has decided to build. Therefore, the characteristics of the construction industry are more similar to those of the service sector than to those of a branch of industry. Consequently, construction can be called a producing service (Syben, 1999). As it is the client who sets off the production of a constructed facility, his specific aims and ideas with respect to the constructed facility and the construction process have to be considered from the start. These aims and ideas are about the place, the type, the dimensions and the design of the constructed facility as well as about the deadline for finishing it. Moreover, by choosing the procurement strategy the client also chooses a certain organisation of the construction project.

Organisation of construction projects and innovation

Traditionally the client chooses an architect, who takes on the task of planning the constructed facility, supervising the construction process and co-ordinating the executing companies. With an increasing number of participants in the project, who are connected with each other, the complexity of the constructional task and with it the demands on the architect are increasing, too. But it is the client who is left with the risks arising from this, as every single company is directly accountable to the client for the services it performed. As a consequence, during the last few years clients have – especially with bigger construction projects – tended to choose procurement strategies which, for example, have only one party to the contract to execute the construction of the facility. This one company then takes on the task of co-ordinating all services that are necessary for the construction with regards to the works` procedure and time. At the same time it takes on the economic risks resulting from the contractual relations with the companies that carry out the services. Co-ordinating can in this case mean to co-ordinate different systems of the constructed facility as described before (like for example carcassing and interior works) or it can include different constructional levels of value added (like for example planning and execution). The highest degree of integration is reached, if a company or a group of companies is responsible for the whole system of a constructed facility over its whole life cycle (Girmscheid, 2000).

The client gains two advantages from this. First of all, he can delegate a part of his tasks to others. This is important, because many clients do not have the qualification to completely fulfil all their tasks. The second advantage is the creative freedom that results from delegating parts of or the whole constructional task to the responsibility of one company. By viewing the constructed facility over its whole life cycle, the interdependencies between the single components of the system „constructed facility“ and the influences of certain life phases on the components as well as on the system on the whole can be recognized at an early point in time and be deliberately designed. This brings about more and more possibilities to find innovative solutions that will optimally transfer the client's aims into a constructional solution (Girmscheid and Hartmann, 2001).

One disadvantage of this procurement strategy is that the client looses the direct control over and the influence on the construction process. While delegating tasks and responsibilities was meant to reduce the client's difficulties in dealing with the complex constructional task, in this case he has to rely on one single company. To a great extent he has to be able to be confident that the company engaged is acting strictly according to his interests and will transfer his constructional aims and ideas into a technically and economically ideal constructed facility (Syben, 1999).

Developing confidence is even more difficult, when there are innovative constructional solutions involved, the effects of which on the constructed facility and the construction process can hardly be assessed because of their novelty. The client can only to a limited extent transfer the risk that is resulting from this to the company, i. e. through guarantees. There will always be uncertainty on the question if the aims concerning quality, costs and time can really be achieved.

QUESTIONS AND METHODOLOGY OF THE EXAMINATION

The following questions directly arise from the last mentioned points:

- Which are the aims a client nowadays has with regards to constructional solutions?
- Which possibilities for innovative constructional solutions does the client see, when following his aims?
- To what extent does the client's choice of a procurement strategy depend on the possibility of implementing innovative constructional solutions?
- Which factors contribute to building up confidence on the side of the client, if the procurement strategy is fostering innovation?
- How does the client solve the problem of uncertainty that goes along with innovative constructional solutions?
- Which conclusions can be drawn for the innovative action of construction companies from examining the client's attitude towards innovative constructional solutions?

It can be assumed that the clients in construction industry will give different answers to these questions. Especially when dealing with a complex constructional task, the clients will handle it differently depending on how often they have already been building. Clients like big companies or the state, who have been building several times, mostly have a lot of experience gained from former projects. They know the companies on the market and often have their own staff for planning, controlling and managing tasks. Because of their competence in construction they are faced with a lesser complexity of the constructional task than clients who – like families or small companies – build only once or seldom. This is why the study, on which this paper is based, concentrated on the small group of professional clients, who often build. Within this group priority was given to private clients, as they have more freedom to choose a procurement strategy than state-run clients have. Furthermore, the study was restricted to a group of clients which is only doing building construction. Included in the study were three banks, one insurance company, one trading company, one airport company and one university. These Swiss large companies build office buildings, branches, research centres etc, in order to use it within their own concern, that is for internal clients. By this they take on two roles, they are the investor and the user. The study is based on semi-structured interviews. The interviews were taken with the heads of the construction and real estate department of the companies. In the following the results of the interviews are presented.

THE CLIENTS` AIMS AND POTENTIALS FOR INNOVATION

The aims a client is trying to reach do not just refer to the constructed facility and its usage, but also to the construction process. This process includes the working on and the transport of physical objects as well as the exchange and the processing of information. It starts with the strategic planning and lasts until the product, the constructed facility, is finished. Its organisational design can be found in the constructional project and the process itself is interacting closely with the constructed facility, because the aims that are connected with the constructed facility are materially transformed in the construction process. The interviewed clients could see useful potentials for innovation through product and process innovations applied to the constructed facility as well as to the construction process.

Aims concerning the constructed facility and product innovation

The predominant aim among the aims concerning the constructed facility, which have gained greater importance during the last few years, is the desire to keep the costs for operation and maintenance low. It is increasingly reflected on the economy of a constructed facility over its whole life cycle and it has been found out that not only the costs of planning and execution are relevant for the economy of a constructed facility, but also the costs of the usage period, which at 70% of the total costs are far more significant.

Another aim concerning the constructed facility is its flexibility. Due to the increasingly shorter product cycles in the manufacturing industry constructed facilities have to be adaptable to changes that result from technological reasons as well as be flexible with regards to its area. This means that constructed facilities have to be planned and built in a way that will make it easy and inexpensive to re-use them later on. This is difficult with extremely specifically used constructed facilities like with kitchens, where a flexible design will soon be uneconomic.

Closely linked to the flexibility is the desired quality of the structure and the facility equipment. Because of the fast changes in usage parts of the constructed facility have to be replaced before their life cycle ends. The degree of quality is therefore chosen according to the period of usage and not necessarily according to the whole life cycle of the constructed facility. In some cases the period of usage is so short that a comparatively low degree of quality is regarded as being sufficient.

According to these aims concerning the constructed facility the client will most of all attach importance to innovative solutions that aim at low costs in usage and flexible structures and facility equipment. Potentials for innovation are therefore mainly to be found in product innovations like new materials or new design principles.

To keep the costs for usage low, as starting-points for innovations especially technical installations for heating, ventilation and climate were named. The following example will illustrate this. A client wanted to build an office building that would save the environment and energy, while this would not affect the working comfort of his staff members. These aims could be reached through different solutions that were innovative at the time they were applied. One of them is for example a thermo-active ceiling that will cool the room in summer and heat it in winter using the concrete of the ceiling as a heat storage. Moreover, by using a combination of brise-soleil and plastered balconies, an ideal shading can be achieved and a totally glazed facade can keep the rooms from heating up. A photovoltaic system produces as much energy as is used by the screens of personal computers.

Up to now the attempts that are made to make constructed facilities flexible mostly concentrate on steel and reinforced concrete framed structures, economically optimal designed ground plans, mobile walls, useful window arrangements etc.

Aims concerning the process and process innovation

The client's aim concerning the process to plan and build a constructed facility in as short a period of time as possible is not new. It takes on a new meaning though, due to the above-mentioned changes in the usage of a constructed facility. If, for example, planning and executing a constructed facility takes two years, during this time the ideas about its usage may have changed considerably. A short period of planning and execution is therefore an essential aim, taking into account the fast amortisation of the invested capital, too.

This leads us to another aim: trying to keep the costs for planning and execution low. This is not new, too, but due to the mutual dependence of this aim and the time for planning and execution it is also essential, although it is more and more loosing its importance as the sole criterion for the placing of orders. It is replaced by a comparison of price and service that technically and economically assesses the constructional solution over its whole life cycle. A prerequisite for this is, however, that the surplus value of a constructional solution is evident.

Here, innovative potentials are mainly to be used through process innovations like for example new construction methods, new machines and equipment or a new organisation of the execution process.

The construction of a test bed for aircraft turbine engines, which had to be done quickly and as inexpensive as possible, can serve as an example for the realization of these process-related aims achieved by process innovation. Due to a lack of space the test bed had to be built on an existing parking lot. Therefore an underground car park had to be integrated into the test bed. As the soil had no good quality, a new process engineering solution, the modified cover-and-cut construction, was developed.

Typology of constructed facilities

Three different types of constructed facilities can be distinguished according to these aims of the client and the innovative potentials connected with them, see Table 1.

Table 1 Typology of constructed facilities

	Constructed facility type 1	Constructed facility type 2	Constructed facility type 3
Usage time	50-70 years without changes in usage	50-70 years with changes in usage	10-20 years without changes in usage
Flexibility	low	high	low
Quality	high, during the whole usage time	high, during single phases of usage	low, during the whole usage time
Costs of the usage	primary	primary	secondary
Costs of planning and execution	secondary	primary	primary
Planning and execution time	secondary	primary	primary
Innovative potentials	product innovation	product and process innovation	process innovation

Type 1 has a life of 50-70 years, during which the usage of the constructed facility does not change. This means that the flexibility of the constructed facility is low, while the desired quality is high. The structure and the facility equipment have a long life and are not exchanged or repaired very often. The reflections on the economy thus focus on the phase of usage of the constructed facility and with it on minimizing the costs of the usage. The costs for planning and execution as well as the execution time play a minor role. Their amount and duration depend on their contribution to the reduction of the costs for the usage. Potentials for innovation can be found in the product, the constructed facility.

Type 2 has a life of 50 – 70 years as well, but its usage is subject to change. As a consequence the flexibility of the constructed facility is comparatively high and the desired quality with respect to the single phases of usage is high, too, while it is low with respect to the whole life cycle. This means that some parts of structures and the facility equipment are designed in a way that their life corresponds to the duration of their single phases of usage. The costs for planning, execution and usage have to be balanced and optimized together. The time for planning and execution in this case is directed towards the quickest possible commission of the constructed facility. Potentials for innovation lie both in the constructed facility and in the construction process.

Type 3 has a life of only 10 – 20 years without changes in usage. The flexibility of the constructed facility is low. The desired quality is low, too, as the structure and the facility equipment are only designed for the short period of the constructed facility's life. As a result of the short life the costs for usage are less important than those for planning and execution. These costs have to be optimized together with the time for planning and execution. Potentials for innovation therefore exist in the construction process.

This typology helps to find out, if the client pursues specific procurement strategies, in order to foster innovative constructional solutions.

PROCUREMENT STRATEGY AND INNOVATION

The choice of a procurement strategy manifests itself in a certain organisation of the construction project. The organisation of the construction project regulates the co-operation of those who are involved in the project and therefore to a great extent determines the possibilities for innovative action. There are two criteria that the clients regard as substantial for choosing the procurement strategy or the organisation of the construction project.

Complexity

The first criterion is the complexity of the constructional task. Complexity in this case means the multitude of components of the constructed facility (parts of the structure, installations) and the diversity of the relations between these components as well as their interaction with the surroundings of the constructed facility. In addition the complexity of the constructional task includes a dynamic aspect. The type and the interaction of the components is not set in advance, when the planning process starts, but is subject to continuous changes. These changes mainly result from the needs and aims of the client that have only been roughly formulated at the beginning of the planning and are only put in concrete terms when the planning progresses.

Due to the multitude and diversity of interactions between the components this means that the different architects and engineers who are involved in the planning have to work together as a team from the start, in order to be able to in time assess the effects that single decisions may have on the constructed facility on the whole and to be able to react to it. Moreover, the clients want this team to be open to further specialists, if necessary. By forming a planning team at an early point in time the clients also lay the foundation for product innovations as they have been described for the types 1 and 2 of constructed facilities. However, including executing companies is often regarded as unnecessary and sometimes even as problematical by the clients.

It is regarded as unnecessary, because the clients do not consider the knowledge on the execution to be of much relevance for a good constructional solution. The reason for this is surely to be seen in the field of activity of the clients. In building construction the demands on the execution are generally regarded as relatively low. Alternative tenders offered by executing companies show that this is not applicable for all constructed facilities in general. These tenders often represent more economical and sometimes innovative alternatives for the execution of the constructed facility that is the subject of the tender. While the clients appreciate alternative tenders by the companies, which mostly refer to the process innovation of types 2 and 3 of the above mentioned typology, they stress at the same time that there are few possibilities for them and that the executing companies often do not have the capacities of time and staff to be able to work it out. It was criticised at this point that some clients regard the working out of innovative solutions by the executing companies as a service that is free of charge.

Including the executing companies in the planning phase is seen as problematical by the clients, because it results in the application of organisational models that do not provide a wide range of freedom for the client to change something later. These organisational models include only one company that is supposed to do the whole execution or the whole planning and execution. The company carries out the constructional task for a flat rate and in exchange takes all the financial risks and the risks with regards to time of the planning and execution. As far as innovative solutions are concerned this actually is an advantage for the clients, because they do not have to take on the particular risks innovations cause. But the flat rate is based on a certain agreement on the services, which leads to a rigorous management of supplements by the companies in case any changes are made later. Organisational forms of construction projects in which the responsibility for the planning and/or execution services is taken by one company are therefore usually only interesting for a client who has a clear concept of his aims from the start. In all other cases the desire to be able to change something later has a higher priority for the client than an increased potential for innovations. Another reason for this is that the clients do not believe that companies offering integrated services are able to develop innovative constructional solutions. This leads to the second criterion that induces clients in construction industry to choose a certain organisation of the construction project – confidence in the companies.

Confidence

Although compared to other clients professional clients in construction industry are in a position to assess constructional solutions, even they lack the special knowledge that is needed to understand and to assess technical details and complex correlations. Where they lack the knowledge, they are forced to trust in the planning and executing companies.

First of all this means to have confidence in the professional competence of the planning companies. The interviewed clients expect the planning companies to have a high level of knowledge, that includes both the latest technical developments and their applications, whether they have been particularly successful or not. Here references play an important role, as they represent the company's experience. Along with constructed facilities that have been carried out by the company competent staff members can serve as references, contributing to the building up of confidence on the side of the client through personal contact either from former projects or by delivering a convincing presentation of the project.

Of prime importance is that the client has to regard himself as a member of the organisation of the construction project and not just as the one who ordered the constructed facility. As a member of the organisation the client wants to be included in discussions on the planning, so that he can take rational decisions. When clients transfer the taking of decisions to planning and executing companies, they consider it to be of great importance that the decision-making is transparent, because in this area they still do not have confidence in the companies. They are not sure, if the companies will definitely provide for the planned quality of the product and sometimes they get the feeling that the companies try to receive a greater margin by performing a low-quality job. Moreover, they do not have insight in the configuration of the costs and therefore lack the confidence that there is a balance between the services and the price.

This is why confidence is a decisive criterion for choosing the procurement strategy and, as a consequence, for the possibility to innovate. For, on the one hand, the formation of a team, in which all those involved in the project are included in time, is a prerequisite for innovative constructional solutions. On the other hand, it is essential for the comprehensive formation of a team, that takes into account both the planning and the execution phase, that the client has confidence in the ability and the willingness of the companies involved to build a constructed facility that meets the client's demands and is technically and economically optimal. The clients emphazised that they do not prefer a certain procurement strategy. They take the decision depending on the situation and on the constructional task.

RISKS AND INNOVATION

The most important characteristic of innovations is their novelty, which is closely linked with another characteristic, the uncertainty. Uncertainty in this case is a situation in which it is impossible to name the probabilities of the relevant outcome, neither subjectively (by experience) nor objectively (statistically measurable). This means that little or no experience with innovative constructional solutions and – as a result of the complexity of the constructional task - the incomplete information cause an uncertainty on the question if the aims of the innovative action will actually be reached. Clients in construction industry are always faced with uncertainty, because they have to make decisions on the construction itself, the deadlines and on financial aspects without being able to get an exact idea of the finished product, the constructed facility. This uncertainty brings about certain risks, which in the case of innovative constructional solutions include an additional aspect. While normally the client's uncertainty is due to his lack of competence in this area, with innovative solutions it is extended by the uncertainty on the part of those who are actually the competent persons in this field. There are a couple of possibilities, how the client can react to these uncertainties.

Transferring risks

One possible reaction is to transfer the risks to the companies and to have confidence in their competence to deal with the risks. The question of building up confidence has already been treated in this paper. It has an effect on the way people handle risks, too. Companies that are accountable for planning and execution will only take on the risks connected with planning and execution, too. The clients have the impression that this causes the companies to look at constructional solutions solely from a point of view of planning and execution. Often the effects on the usage phase of the constructed facility are not taken into account. This is why the clients are sceptical about the product innovations of types 1 and 2 of the typology, where the success of the innovative action can only be determined during the usage phase and the clients are forced to take on the major risks. As a consequence, clients rather accept the process innovations of type 2 and 3, where the positive effects already manifest themselves at the end of the construction project, for example in the economy of time and costs, and where the companies take the risks. It would therefore be logical to make one of the planning and/or executing companies accountable for the operation and maintenance of the constructed facility. But the clients still have a sceptical attitude towards contractual arrangements like this, because the companies in this case demand an extra payment for taking on the risks and the clients believe that it is still impossible today to sufficiently enough estimate the costs for the future operation and maintenance, so that they are not in a position to assess these additional costs. As long as this is not possible, they will prefer to take the risks of the usage period themselves.

Minimizing risks

The client will do his best to keep the risks as low as possible by collecting as much information as possible on the potential effects of innovative solutions. There are several sources of information he can use for this purpose. If the solution is only new to the client, he will ask specialists who already gained experience in realizing this solution. However, his own competence in the field of construction is of great importance, too. A client will have his own department of architecture and engineering, which is acting independently on the market and by this is permanently able to gain new technical knowledge and experiences.

Another source of information are objects of reference, where a certain solution has been applied in a similar way. The fact that simply copying innovative solutions may cause problems can be illustrated on the example of Corten steel. This steel alloy, which is oxidising to a certain extent thus producing a passive protective layer and making the application of a protective coat unnecessary, had been used for the first time in the US and was discovered in Europe later, too. The Europeans made the same mistakes the Americans had made earlier disregarding that this material requires a special structure. Whole buildings had to be demolished as a consequence of this.

This is why clients nowadays increasingly rely on expert's reports. However, tests made in laboratories in connection with this only have a limited meaning, as building material and components are always examined isolated from the whole system of the constructed facility and their long-term behaviour can only to a limited extent be simulated.

Taking on remaining risks

In the end there are always risks left which have to be taken by the client. The amount of risks the clients are willing to take is largely depending on the surplus value that is expected from the innovative solution. This could for example be considerable price benefits, savings in energy or low maintenance costs. The prerequisite for this, however, is that the risks have to be known and can be estimated. Solutions with a high degree of novelty are therefore hardly ever accepted by the clients.

A company culture fostering innovations finds its expression in the willingness to take the risks that come along with innovative solutions. A company culture fostering innovation obviously had a positive effect on the development of innovative constructional solutions and dealing with the risks involved in the companies of the interviewed clients, too. The department for construction and real estate of one client for example has a far-reaching scope of action. The management only sets the goal in advance, while the department is free to formulate the demands on the constructed facility. This encourages them to develop good constructional solutions. At the same time the department has budgets at its disposal, i.e. an internal energy fund, with the help of which it is possible to finance extra costs caused by innovative solutions.

CONCLUSIONS FOR THE INNOVATIVE ACTION OF CONSTRUCTION COMPANIES

Based on the results that have been presented here some recommendations for the innovative action of construction companies can be made:

- Principally the client's requirements include both product and process innovations. However, many construction companies nowadays not only lack the financial resources and resources in staff, in order to use the innovative potential, but also the ability to do so. This is why introducing an innovation management is one of the most important tasks of companies in construction industry.

- Along with the internal preconditions there has to be a relationship based on confidence between the clients and the planning and executing companies, so that innovations can be successfully developed and introduced. It is the confidence that decides, if the client is willing to transfer the competence to make decisions to the companies thus providing freedom for innovative action. The companies can gain the client's trust in them mainly by showing their competences and allowing insight in the way they make decisions. For this purpose they have to increase their own marketing activities. This does not just mean sending advertising leaflets, but it should also and especially include the manners and behaviour of staff members during the construction process. Only by this competence and transparency can be communicated effectively.

- The aspect of confidence is linked to the risks the clients are willing to take in connection with innovative constructional solutions. Clients will only accept innovations, if the advantages and risks of the solution can be clearly assessed. For the companies this means that they have to keep their technical knowledge at the latest level, that they have to find projects which have been executed in a similar way, that they have to learn from mistakes which were made in other projects and, last but not least, that they have to present the solutions they suggest in a convincing way.

- Due to the complexity of the constructional task the professional knowledge of different companies has to be united. Here team work is the key to innovative constructional solutions. For this purpose the ideas of prestige and competition, which are still quite common in construction industry, have to be overcome.

- One of the difficulties that prevent the clients from choosing procurement strategies which are fostering innovation is the fact that the clients often want to change some parts of the planned constructed facility later on or that they can only name their precise aims while the planning process is already going on. This is a challenge for the companies to try and help the clients to be able to formulate their aims at an early stage. Technical aids like visualizing and methodical aids like Quality Function Deployment should be increasingly tested for their applicability, should be further developed and applied. The same is true for aids for assessing life cycle costs.

As these recommendations are only based on examinations of a certain group of clients in construction industry, other groups of clients should be taken into account in further studies. It is only by this that a far-reaching understanding of the needs and the attitude of clients towards innovative constructional solutions can be developed and measures for fostering the innovative action in construction industry can be successfully worked out.

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Construction Sector System and Innovation in Stock Management

Jean CARASSUS

Construction is playing a new role within the economy. It is no longer focused on massive production but on the services provided by the built environment. This evolution calls for a new approach of the construction industry summed up in the "construction sector system" analysis. It also calls for new methods to study innovation in services activities. Some elements of such a new methodology are implemented to analyze innovation in rental housing companies.

A NEW ROLE OF CONSTRUCTION WITHIN THE ECONOMY?

The economic growth experimented by most developed countries between the late forties and the beginning of the seventies was succeeded by a recession period lasting until the beginning of the nineties in the United States and until the end of this decade in Europe. This recession period represented mutation times.

In the general evolution of the economy, what kind of mutation did the construction industry face during those mutation times in several developed countries?

Between the late forties and the beginning of the seventies, the role of the construction industry was to complement the significant and relatively regular economic growth through the massive development of housing projects, non-residential buildings, and civil engineering infrastructures.

The dimension of the construction stock developed within the phase of growth has become highly significant in several developed countries. So far, the refurbishment and maintenance works of such stock in France, the United Kingdom, Italy and the Scandinavian countries, amount to approximately half of the construction firms business, including civil engineering projects (Carassus, 1999).

Furthermore, both firms and civil services have turned the upgrading of their stock management into an area of increasing concern. The quality and the reasonable cost of the service rendered by their buildings and civil engineering infrastructures have become of the essence.

The popularity gained by the « Facilities Management » trend translates this concern, while the professionalization of in house building management or the outsourcing of this management are being fostered.

The expansion of processes not only in charge of production but also built environment management, over long periods of time, reflects the same evolution. In fact, several mechanisms have been created to foster such trend, such as Private Finance Initiative (PFI), Private and Public Partnership (PPP).

Such evolution is all the more marked as the profitability of service activities related to maintenance and management is higher and less cyclic than construction site activities.

Therefore, our hypothesis is that the mutation faced by the construction industry in the nineties changed its *role within the economy.*

While during the 1950-1960-1970 period, the goal of construction was to massively build all the works necessary to meet the needs of the economy, since the nineties the emphasis is placed on the management of the service rendered by such works all along their life cycle.

The requirements of sustainable development, which focus on the need to increasingly master medium and long-term consequences, not only regarding production, but also management of the works during their whole life cycle have strengthened this change of role within the economy. This focus on the service rendered by the works calls for a new approach of the construction industry.

FROM THE CONSTRUCTION INDUSTRY TO THE "CONSTRUCTION SECTOR SYSTEM"

The mesoeconomic literature[1] offers several possible unifying concepts: industry sector, production chain, economic meso or sector system, and industry cluster.

Following de Bandt (1991) and Gilly (1997), and taking into account the observations of Saillard (1995), du Tertre (1995) and Boyer (1990), we will use the economic sector system concept (Carassus, 1998, 2000).

The construction sector system can be defined as *the organized complex of relations between productive and institutional actors taking part in the production*

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[1] The mesoeconomic level is intermediate between the macroeconomic level centred on the national economy and the microeconomic one focused on the firm.

and the management of services provided by the built structures, throughout their life cycle.

The economic sector system as applied to the construction sector is close to the concept of "construction product system" suggested by Australian industrial economists (AEGIS, 1999).

The construction sector system is wider than the construction industry. It is made of three main groups of activities.

The first group of activities concerns the *continuous management of the existing stock of structures*. Continuous management is a three-dimensional service activity: asset management (strategic stock management by decisions to purchase, sell, renovate, demolish, build), property management (heavy renovations and administration), facilities management (managing services provided to the end-user, care taking, operation, everyday maintenance). Profit in this first group of activities is recurrent, not depending on the cycles and may be high.

The second group of activities concerns the *short-lived design and complex production assembly on itinerant sites*. This group of activities covers on the one hand service activities involving project management (order, design, co-ordination and control of new construction and refurbishment operations) and, on the other hand, the construction firms works. Profit in this group of activities is volatile, depending on the construction cycles and for the construction firms often low.

The third group of activities is focused around the *industrial production and distribution of materials, components, equipment and plant* implemented, assembled, installed by construction firms on worksites. Profit in this third group of activities depends of the industry; it is often linked with the construction cycles[2].

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[2] Being the subject of work in progress within a CIB (International Building Council) group, this sector system approach is being implemented in nine developed countries. The « Construction Industry Comparative Analysis » Project group, which we are co-ordinating, is a joint group of CIB Working Commission n°55 « Building Economics » and n°65 « Organisation and Management of Construction ». It aims to compare the Australian, British, Canadian, Danish, French, German, Lithuanian, Portuguese and Swedish construction industries on the basis of this method.

Table 1. Taking into account services: construction sector system approach versus construction industry analysis.

	Construction industry Analysis	Construction sector system approach
The industry aim	To build buildings and infrastructures	To produce and to manage the services provided by the structures throughout their life-cycle
Role of the existing stock	Not taken into account	Very important role of the existing stock: - Weight of the stock - High part of the repair & maintenance works - Important role of stock management
Activities	Construction firms	- Stock management firms - Project/site (clients, engineering, construction) firms - Industry (materials, machinery) and distributors
Profit formation	Depending on cycles	- Stock management: recurrent, non cyclical, high - Project/site: cyclical, low - Industry: depends on the industry, linked with the construction cycles
Processes	Especially new construction	Three kinds of operational configurations of actors: - Production - Production & management - Management
Institutional regulations	Sometimes taken into account	- Structures regulations (building permits, construction codes, product and service certification) - Firms regulations (firms standards, labor management, prices) - Environment of the firms' regulations (procurement methods, funding, tax, R&D support, education and training).

When dealing with innovation, one of the consequences of approaching construction in terms of a sector system is to prioritize service innovation, particularly regarding the management of the service rendered by construction works.

However, most of the research done on innovation in the construction field deal with production (CIB 1997, Manseau and Seaden, 2001). Methodologies focused on production and technological innovations are not suitable to services activities. It is therefore necessary to take into account recent research done on innovation in the field of services.

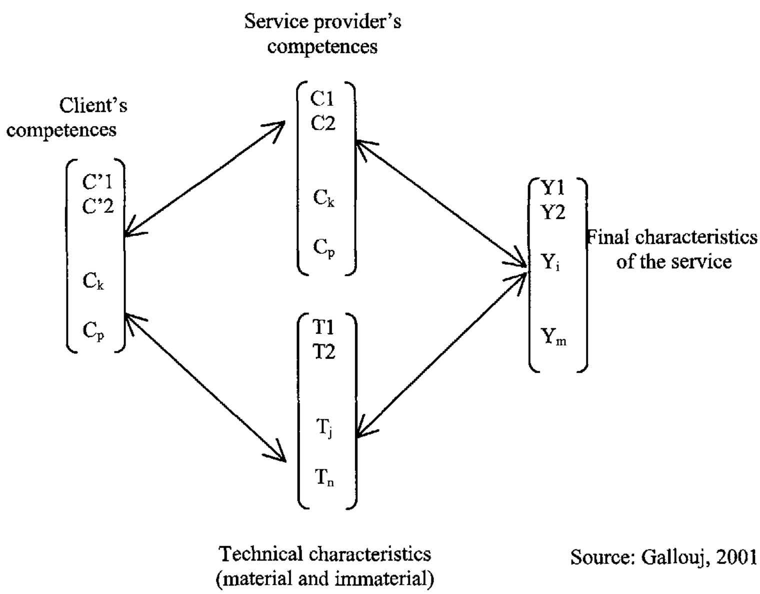
SERVICE: A SET OF CHARACTERISTICS AND COMPETENCES

The overall framework of the analysis used is that of both institutional economics (Amable and alii, 1997, Boyer and Didier, 1998) and evolutionist economics (Nelson and Winter, 1982). The methodology used for the study of innovation in the stock management services is the one stated by Gallouj (Gallouj and Weinstein, 1997, Gallouj and Sundbo, 2000, Gallouj, 2002). Such methodology results from the analysis of the service economy premises of Gadrey (1996) as well as Saviotti and Metcalfe (1994) on technological change indicators.

F. Gallouj highlights *five kinds of services*, namely: « quasi products » (whenever the service is highly standardized), operational or manual services, informational or relational services, intellectual or professional services, and finally the combination of products and services.

According to the analysis perceiving *service as a set of characteristics and competences*, the final characteristics of the service result from the simultaneous mobilization of competences (coming from the service provider -C_p- and the client -C'_q-) and technical characteristics T_n (material and immaterial).

Figure 1: Service as a set of characteristics and competences



Innovations are particular movements of those characteristics. Innovation is developed according to different *innovation models*. Gallouj proposes a six-model typology of innovation.

Radical innovation proposes a completely new service, that is to say a new set of characteristics and competences C_p, C'_p, T_n, Y_m.

"Improvement" innovation just modifies the significance of a given characteristic.

« Incremental » innovation deals with the addition of a supplementary service characteristic. *« Recombinative » innovation* combines several services in order to create a new one.

« Ad hoc » innovation is an innovation that suits the particular needs of a client. *«Formalization» innovation* is aimed at formalizing, formatting, and standardizing both the provider's competences and the service characteristics.

Innovations evolve according to different possible *innovation trajectories*. There are four kinds of innovation trajectories, namely: the *material transformation* trajectory ΔM (Y), which corresponds to a modification in the material basis of the service; the *information processing* trajectory ΔI (Y), corresponding to new data, new uses of data, network sharing of information, etc; the *methodological* trajectory ΔK (Y), dealing with the implementation of formalized methods for knowledge processing; and finally, the *« pure » service* trajectory ΔC (Y) corresponds to the direct mobilization of competences, regardless of any material, informational or methodological support.

It is suggested to test this methodology with seven important European rental-housing companies, which have decided to implement an innovation process within the framework of an important research and development contract with the European Commission.

HOUSING MANAGEMENT

The SUREURO Project (SUstainable Refurbishment EUROpe) is aimed at innovating the refurbishment and management processes of housing stocks. The senior management of seven companies that have the support of research centers and consultant organizations pilots the project[3].

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[3] This four-year project (March 2000 - February 2004) involves seven social housing companies and thirteen research centers and consultant organizations. It is worth 10 M € (10,9 M US $), half of which is financed by the European Commission. The project partners

Bearing in mind the five-category service typology, the management service of rental housing (and construction stock, in general terms) is obviously the *combination of products and services* (such as hotel accommodation, transport or tourism industry). This combination of buildings and services is handled by the housing manager, who calls for the support of several suppliers (cleaning contractors, lift operators, heating firms, maintenance contractors, and so forth).

These suppliers can play an important role (positive or negative) in the implementation of the innovation plan. Therefore, it would be worthwhile to complete Figure 1 by introducing competences C'_p of the housing manager's providers, as well as those of the user, i.e. in this specific case, the tenant and this yields C''_p.

It is equally important for both the manager and the suppliers, to differentiate between front office (direct relationship with the user) and back office activities (service management process), as several authors do (Teboul, 1999, Veltz, 2000).

Figure 2 gives a simple representation of the housing management activity as a set of characteristics and competences.

INNOVATIONS, CHARACTERISTICS AND COMPETENCES

The innovations implemented within the SUREURO project are mainly the result of an innovative process of know-how transfer from a « sender » enterprise to « receiver » ones, together with improvements of the transferred know-how by the latter and the research centers.

Ten innovations will be taken into account for the analysis. Table 2 describes the changes made on the characteristics (final and technical) and competences (the housing manager's, the suppliers' and the tenants') required for the implementation of innovations or resulting from them.

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come from seven countries: Denmark, Finland, France, Germany, Netherlands, United Kingdom, Sweden.

Figure 2: Housing management as a set of characteristics and competences (simplified scheme)

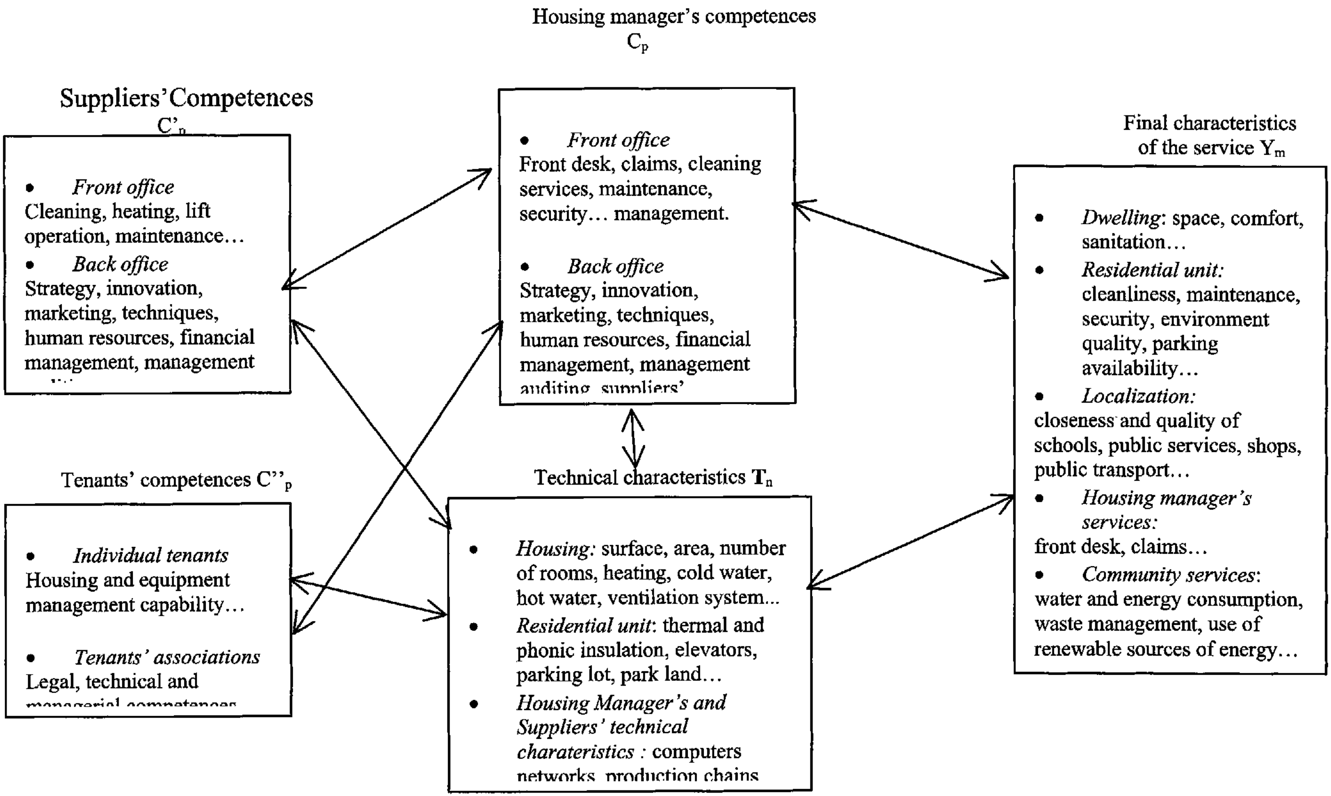

Table 2. « SUREURO » innovations and alteration of the characteristics and competences

Innovation	ΔY_m Final characteristics of the service	ΔC_p Housing manager's competences	$\Delta C'_p$ Suppliers' competences	$\Delta C''_p$ Tenants' competences	ΔT_n Technical characteristics
1 « Sustainable » portfolio strategic management	Δ «sustainable» services for the community	Δ strategy, marketing, financial aspects			Δ information system
2 New information system on residential units and corresponding market	Δ adaptation of residential units to the market	Δ information system and analytical capability			Δ information system
3 « Sustainable » management of refurbishing project	Δ water and energy consumption, waste management	Δ human resources, suppliers monitoring		Δ capability for making proposals	
4 New methods for tenants' participation	Δ refurbishment and housing management tailored to the tenants' needs	Δ consultation capability	Δ capability of architects, design offices, construction companies	Δ capability for making proposals	Δ different works resulting from consultation
5 Residential unit with low-cost energy services « 3 liters »[4]	Δ heating costs Δ energy consumption	Δ providers co-ordination	Δ capability of architects, design offices (new materials)	Δ tenants behavior	Δ insulation, heating production and management
6 Solar panels for water heating	Δ renewable sources of energy		Δ industrial material industry services		Δ water heating systems
7 Sorting of household refuse	Δ refuse management		Δ refuse management services		Δ refuse management system
8 Sorting of refurbishing site waste	Δ waste management		Δ construction company services		Δ site waste management system
9 New consumption information system (gas, electricity, water)	Δ cost of heating and water Δ energy and water consumption	Δ information system			Δ information system
10 Tenants' training in environmental management	Δ environmental management by tenants	Δ training		Δ managerial capability	

[4] The « 3 liters » residential unit results from a refurbishment process that makes the annual consumption of energy swing from 20 equivalent liters of fuel per m² to 3 liters per year, as compared to 7 liters for ordinary refurbishment.

The analysis method is productive: it mainly allows characterization of innovations, according to the highly variable scope of the conditions to be met for successful implementation and the equally variable scope of the improvements made to the final service rendered to the users and the community.

It is worth highlighting that except for innovation number 4 (new consultation methods with tenants) and number 10 (tenant's training in environmental management), the innovations analyzed mainly concern back office activities of the manager and the suppliers.

INNOVATION MODELS AND TRAJECTORIES

According to Gallouj's six-category *innovation model,* most of the innovations are either "improvement" or "incremental" ones.

Table 3: « SUREURO » innovations and innovation models

"Improvement" innovations
5 Residential unit with low-cost energy «3 liters» 6 Solar panels for water heating 8 Refurbishing site waste management 9 New information system on consumption (gas, electricity, water
"Incremental" innovations
2 New information system on residential units and corresponding market 3 «Sustainable» management of refurbishing projects 7 Sorting of household refuse 10 Tenants' training in environmental management
Ad hoc "innovation"
4 New methods for tenants' participation
"Formalization" innovation
1 «Sustainable» portfolio strategic management

It is also interesting to use Sundbo's four-category typology (1998) inspired by Schumpeter's one (1934): service innovations (new service), process innovations (change in the service elaboration procedures), organizational innovations (change in the management modes), marketing innovations (marketing, sales, and so forth).

Table 4: « SUREURO » innovations and innovation typology

Service innovations
5 Residential unit with low-cost energy «3 liters» 7 Sorting of household refuse
Process innovations
6 Solar panels for water heating 8 Refurbishing site waste management 9 New information system on consumption (gas, electricity, water)

Organizational innovations
1 «Sustainable» portfolio strategic management 3 «Sustainable» management of refurbishing projects 4 New methods for tenants' participation 10 Tenants' training in environmental management
Marketing innovation
2 New information system on residential units and corresponding market

The *innovation trajectories* typology is functional, with only one category excepted. Four innovations deal with a material trajectory, three with an informational one, and other three with a methodological one. None of them follows a « pure service » trajectory, without any material, informational or methodological supports. This kind of trajectory must hardly concern a kind of service combining products and services; it may concern « pure » services, such as lawyers, doctors, etc.

Table 5: « SUREURO » innovations and innovation trajectories

Material innovation trajectories
5 Residential unit with low-cost energy «3 liters» 6 Solar panels for water heating 7 Sorting of household refuse 8 Refurbishing site waste management
Informational innovation trajectories
2 New information system on residential units and their market 9 New information system on consumption (gas, electricity, water) 10 Tenants' training in environmental management
Methodological innovation trajectories
1 «Sustainable» portfolio strategic management 3 «Sustainable» management of refurbishing projects 4 New methods for tenants' participation

CONCLUSION

It is clear that the analysis we propose on the evolution of the construction industry (from works to service, from production to management, and from flows to stock) calls for a new methodological approach on the study of the service activities and innovation within the field of services. Such methodological approach must be tailored to the specific features of construction sector. The methodology broad lines tested in this document show the first elements, which in the future should be identified and delved in a dynamic way into within more significant implementation areas.

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KNOWLEDGE MANAGEMENT, INTELLECTUAL CAPITAL AND INNOVATION: THEIR ASSOCIATION, BENEFITS AND CHALLENGES FOR CONSTRUCTION ORGANISATIONS

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ABSTRACT

This paper is primarily informed by a research study, which is aimed at improving our understanding of the role of knowledge management (KM) and intellectual capital (IC) assets on organisational innovations in project based industries. It employs a combination of research approaches, including ethnographic interviews, semi-structured interviews, postal questionnaires and the analysis of archive documents. The study takes a social science perspective to explore the perceived benefits and challenges associated with managing knowledge and intellectual capital in organisations. In addition, it explores how organisations monitor and evaluate, if at all, the achievements of knowledge assets. Similarly, the factors that favour effective implementation of KM and IC in organisations are examined together with the link between such factors and their role in organisational innovations. Innovation can be considered as the successful exploitation of an idea, which is new to the unit of adoption. Viewed as a process dependent on the tacit knowledge of individuals, motivated by the capacity for intuition and creativity in every human being, it could be inferred that the cultivation of an environment conducive to human creativity and freedom of thought is essential for innovation generation. This paper argues that KM and IC management is important pre-requisites for this process to succeed. It concludes that KM and IC contribute to process and product innovations in different complex *ways. The role of culture, networking (systems and people), motivation, organisational structure, strategy and innovation trajectory are important in this regard. From a construction industry context, there is very little empirical study on the measurement of the contributions of knowledge management and intellectual capital on incremental and radical innovations in projects and in the wider organisational context. There is therefore ample scope for research in this area for the benefit of the practitioner community.*

Keywords: Innovation, Intellectual capital, Knowledge management

INTRODUCTION

In the last ten years knowledge management (KM) has emerged as a significant concept, both in the academic world and in practice. Numerous studies have documented the changing nature of business environments from an industrial age to an 'information age' and 'knowledge society' (Scarbrough *et al.*, 1999). Knowledge is fast overtaking capital and labour as the key economic resource in advanced economies (Edvinsson, 2000). However, the management of knowledge is a challenging issue that requires clear understanding. It has been suggested that strategies, processes and systems are required to exploit the existing knowledge assets or 'intellectual capital' (IC) and to encourage the generation of new knowledge assets within organisations (Egbu *et al.*, 2001a,b). Moreover, knowledge management (KM) is emerging as a vital activity for organisations to preserve valuable knowledge and exploit the creativity of individuals that generates innovation.

Innovation is viewed as a major source of competitive advantage and is perceived to be a pre-requisite for organisational success and survival (Egbu, 2001a; 1999). The ability to innovate depends largely on the way in which an organisation uses and exploits the resources available to it. A vital organisational resource, at the heart of innovation, is knowledge (Nonaka and Takeuchi, 1995). Among the first to incorporate KM and IC into the organisational fabric were the Skandia Insurance firm. Skandia appointed a Director of IC in 1991, which sparked others to create new appointments of chief knowledge officer (CKO) or chief learning officer. Increasingly, KM has become an explicit reality and many organisations have formally implemented KM strategies or created KM departments. KPMG (1998) conducted a multi-sectoral study in which 43 per cent of organisations have a KM initiative in place. Of these, one in ten considered KM to be 'transforming' the way in which they do business (as cited in Robinson *et al.*, 2001b). Thus, KM is becoming increasingly important for organisations wishing to improve performance and competitiveness.

Understanding how organisations manage knowledge assets and IC involves due cognisance of a number of factors. It involves an understanding of the strategies that underpin KM practices within organisations, the structure and culture that sustains KM, the tools and technologies that support KM and how organisations measure the effects of KM. Empirical investigation of these factors will help to identify the ways in which KM and IC affect organisational innovations.

RESEARCH METHODOLOGY

The research on which this paper is based was conducted between October 2000 and October 2001. The research employed a combination of qualitative and quantitative research methods. Nineteen (19) ethnographic interviews were conducted among five UK project-based organisations to reveal contextually rich descriptions about the nature of KM in these organisations. The interviewees were chosen from senior management, middle management and junior level personnel. These interviews conducted served as multiple case studies. To supplement these findings postal questionnaires were distributed to project-based organisations in UK construction, manufacturing, aerospace and the utilities. Fifty-five (55) usable questionnaires were received. Of these, 40 were from the construction industry. The interviews were analysed using the NVIVO software package that assisted in establishing relationships between variables. The postal questionnaires were analysed statistically using the SPSS software package.

CHALLENGES ASSOCIATED WITH MANAGING KNOWLEDGE IN CONSTRUCTION

Typically, the UK construction industry contains a small number of relatively large firms and a very large number of quite small firms. About 95% of construction firms employ fewer than eight people. The fragmentation of the construction industry reflects the economics of production, encouraging small firms organised by trade or craft. Construction firms typically involve relatively low capital investment. There are also relatively low barriers to entry and exit of firms within the construction industry.

There are characteristics of small firms, which impact upon their ability to access and transfer knowledge. Firstly, this is related to their perceived technological weakness (specialised range of technological competencies, inability to develop and manage complex systems, inability to fund long-term and risky knowledge management programmes). Again, investment in formal and informal training and education in the acquisition and sharing of requisite knowledge is more challenging for smaller than for larger organisations. Other perceived dis-advantages of small organisations include little management experience, power imbalance if collaborating with large firms, difficulty in coping with complex regulations and associated cost of compliance (Rothwell and Dodgson, 1994). However, small size organisations could be said to have organisational strengths, which could stand them in good stead for managing knowledge assets. In the main, small firms often do not need the formal strategies that are used in large firms to ensure communication and co-ordination. This less-formal strategies in small firms, it could be argued, ease the communication of knowledge, improve informal networks, increase speed of decision-making, improve the degree of employee commitment and receptiveness of novelty (Rothwell and Dodgson, 1994). Smaller organisations also tend to react faster to changing market requirements.

The construction industry is characterised by projects, by short-term employment and by temporary coalitions of contractors and subcontractors. It is also perceived to have an adversarial culture. It could be argued that the nature of projects does not lend itself to knowledge management practices. For a start, projects are temporary events whereas knowledge management programmes are almost always seen as long term investments. Projects are also seen as temporary coalitions of individuals and teams who come together for the duration of the project and then disband after the end of the project. This latter characteristic of a project poses some challenges in terms of knowledge management. These include the difficulty of building trust among project team members, motivating project staff and operatives during the project period. These are important issues for knowledge management. The project culture is also likely to be different from an organisational culture. The project manager also has the project objectives (e.g. cost, time, quality, safety, and environmental issues) as the overriding project concerns as it is on the fulfilment of these objectives that he/she is normally judged. There is also the added complication in project environment, which is the fact that there may be members of the wider project team (i.e. those involved in the project supply chains) who, for many reasons, may not have the interest, drive and commitment towards knowledge management. There are also those who are committed to the project for a very short period (e.g. a week or two or even less) and who are bound to ask the question - 'what is there for me (WITFM) in knowledge management anyway?

It is however worthy of note that that project knowledge is not just made up of the explicit type which is easily documented and archived. There is also the tacit or implicit Knowledge. It is equally important to remind us that projects are made up of people, many of whom have requisite skills, knowledge, competencies and wisdom. Some will also bring with them knowledge dimensions from previous jobs, which could provide innovative solutions to their new projects. Knowledge management from a project perspective is about harnessing individual and project knowledge to the benefit of the project. The challenges, therefore, for project managers and leaders of projects are, firstly, to recognise the particular constraints imposed on knowledge management processes by the project environments. Secondly, to find the means of creating, transferring, sharing, implementing and exploiting individual and project knowledge in such a way that they lead to project success and provide benefits to project clients.

Many innovation processes in the management and procurement of construction activities are becoming increasingly interactive, requiring simultaneous networking across multiple 'communities of practice' such as professional groups, functional groups and business units. This networking involves communication and negotiation among different social communities with distinctive norms, cultural values and interest in the innovation process. This therefore means that knowledge needed for innovation is distributed within organisations and across organisational boundaries through different supply chains. In the UK construction industry, there is a steady increase in collaborative working practices, such as partnering, alliances and joint ventures. In addition, projects are growing in complexity and cost, and clients' demands and expectations are also increasing more than ever before. This presents a situation where organisations have to collaborate and share knowledge, skills and expertise, in order to meet the needs of the clients. In sharing knowledge, however, organisations need to be both mindful of the communicative behaviours and practices associated with knowledge exchange as well as the 'knowledge paradox'. Organisations will have to be open to formal and informal information and knowledge flows from both networks and markets. At the same time, they must protect and preserve their intellectual capital and knowledge base because it is upon this latter point that survival depends.

KNOWLEDGE MANAGEMENT, INTELLECTUAL CAPITAL AND INNOVATION

There is some inconsistency and confusion between the terms KM and IC. There is an abundance of literature on both, each dealing with the same issue – the value of knowledge as an organisational asset. However, few make a direct link between the two concepts. IC was neatly defined at the ICM Gathering in 1995 as "knowledge that can be converted into profit" (as cited in Harrison and Sullivan, 2000, p.34). KM is about the process of conversion and how knowledge is effectively managed to produce profit in an organisation. IC is made up of three components: human, structural and customer capital (Edvinsson, 2000; Bontis, 1998; Bontis *et al.*, 2000). Structural capital describes the internal structure of an organisation, such as its strategies, core competencies and culture, which is always context specific. Customer capital encompasses the external intangible assets of an organisation. External forces play a part in determining the market position and strength of an organisation. Customers are the principal determinants of this position (Smith and Saint-Onge, 1996). However, it is asserted that the human capital in an organisation is the most important intangible asset, especially in terms of innovation (Edvinsson, 2000; Stewart, 1997; Brooking, 1996). The unique tacit knowledge of individuals is of immense value to the organisation as a whole, and is the "wellspring of innovation" (Stewart, 1997). Identification of the different types of knowledge available to an organisation is the first step to understanding how to manage them. Therefore, KM is intrinsically linked to IC.

An important aspect of the study on which this paper is based is concerned with the impact of KM and IC on organisational innovations. The study therefore attempts to assess the ways in which project-based organisations foster innovation through effective management of knowledge and IC.

The views of the respondents to the postal questionnaires were sought as to the extent to which KM, whether informally or formally, contributed to innovation. By responding to a list of innovation constructs, the respondents provided this information using the following rating scales: 'to a very high extent', 'high', 'low', 'not at all' and 'not applicable'. The results are presented in Table 5.1.The categories 'to very high extent' and 'high' were combined. The percentage responses were calculated and presented in descending order of KM impact on innovation.

Table 5.1: The impact of knowledge management on innovation

INNOVATION CONSTRUCTS	Responses (%) Very high/high N =52
New technology that has internal benefits to the company	55
New process that has benefits to the company	49
New approach to providing services to customers/clients	40
New procedures for obtaining goods/services	35
New product that provides competitive advantage for the company	35
New external relations e.g. partnering, joint ventures	31
New administrative policy e.g. incentive schemes, bonuses	29

An examination of Table 5.1 reveals that about 50 per cent of the respondents noted that effective KM could lead to the exploitation of new technologies and new processes to benefit the organisation. However, many of the respondents did not perceive KM to make a very high/high contribution to other types of innovation. Perhaps this relatively low rating is, in part, to do with the fact that organisations do not have measuring instruments to capture the impact of KM on innovation. This tends to support another finding (see below) of the study relating to the lack of formal measurement of KM and IC in project-based organisations. Moreover, other findings have suggested that most of the project-based organisations that participated in the questionnaire do not have highly developed KM strategies, structures or culture. It is asserted that there is a lack of awareness about the benefits of KM specific to each organisation and how KM has the potential to contribute highly to innovation. There are different types of innovations in project-based organisations. Those listed in Table 5.1 are seen to be important to the competitive advantage of project-based organisations. A further observation of Table 5.1 reveals that 55 per cent of respondents claimed that KM makes a very high/high contribution to the development of new technologies in an organisation. This suggests that respondents associate KM programmes with the implementation of new IT more than other types of innovation. The wider implication to this is that KM programmes are being viewed as a mechanism to further the dominance of IT in the workplace. Growing pressures on project-based industries to save time and money by incorporating technologies into the business process may be having an impact on the types of innovation being generated. Only 35 per cent of respondents noted the contributions made by KM, to the introduction of a new product, as being very high/high. Egbu (1999) argues that "a key feature of the construction industry is the domination of it's product" (Egbu, 1999, p.119). The impact KM is perceived to have on process innovation is marginally higher. Although the scores remain low, the introduction of new processes and new approaches to providing services to customers were all ranked slightly higher than product innovation. It could be suggested that this indicate a marginal awareness that KM has a greater impact on the introduction of new processes rather than new products. In a study of four innovative construction companies Egbu (1999) states that the 'real' innovation which changed the organisations' capabilities and provided competitive advantage, is the shift to process from product.

MEASURING THE IMPACT OF KNOWLEDGE MANAGEMENT IN ORGANISATIONS

Organisations innovate in different ways. Project-based industries are subject to a range of constraints that impact upon them in different ways. Therefore, the way in which each organisation measures the success of innovation is different and should be understood in the context of that organisation. Understanding the innovation trajectory which an organisation embarks upon gives us a better understanding as to whether the organisation has been successful at innovating or not.

The postal questionnaires generated responses relating to the extent to which project-based organisations had formal measurement systems to measure the contributions of knowledge or IC assets. The responses about formal measures of

KM were also broken down into groups according to the size and types of industry and presented in Table 6.1.

Table 6.1: Formal measurement of KM in project-based organisations

Size of Organisation	**Industry Sector**	**Formal Method for Measuring Knowledge Management**		**Total N = 46**
		YES	NO	
SMALL	Construction		7	7
	Manufacturing		4	4
	Aerospace		2	2
	Utilities		1	1
Totals		-	**14**	**14**
MEDIUM	Construction	1	8	9
	Manufacturing		1	1
	Aerospace		1	1
	Utilities		2	2
Totals		1	**12**	**13**
LARGE	Construction	I	15	16
	Manufacturing		2	2
	Aerospace		1	1
Total		1	**18**	**19**

From Table 6.1, it is evident that only 2 (or 4.6%) of the 46 valid respondents indicated that their organisations had a formal method of measuring the effects of KM and IC. One is a medium-sized construction organisation and the other is a large construction organisation. It is possible that these organisations have greater economic power than smaller organisations and therefore, have invested more in formalising policies for improving competitive advantage. It is recommended that further research be done into developing opportunities for smaller enterprises in the formal measurement of KM.

There are many dimensions to consider when attempting to implement a formal measurement programme to capture the impact of KM and IC. One main challenge associated with measuring the effects of KM and IC is deciding what exactly to measure. There is a danger that too many measures will obscure the focus of organisational goals. Organisations should aim to only measure what is strategically important for growth and meeting business imperatives. Managers should not lose sight of the strategic goals specific to the organisation. In project-based industries the measurement of KM is, indeed, a challenging issue. The operational environment is characterised by fragmentation and diversity. In such an environment, knowledge and IC is constrained to individual projects and quantifying the overall effects of this requires enhanced transferability of knowledge across project teams. The effect of knowledge and IC on individual projects does not reflect the overall performance of the organisation, so the challenge for project-managers is to somehow integrate these processes.

As aforementioned, only two respondents claimed to have a formal system for measuring the effects of KM and IC. Further investigation reveals that both respondents measure the contribution of KM to new ideas and existing systems and processes highly (see Table 6.2).

Table 6.2: The extent to which the contribution of KM is measured

Organisational Variables	**Respondent A**	**Respondent B**
Contribution of KM to meeting client/customer needs	Low	Very High
Contribution of KM to new ideas	High	High
Contribution of KM to existing systems and processes	High	High

In addition, it is evident that a difference occurs in the measurement of the contribution of KM to meeting client/customer needs. Respondent A reports a low degree of measurement while respondent B reveals a very high degree of measurement. This result suggests that in the two organisations that formally measure KM, there is a clear commitment to measuring the contribution of KM to the specified variables.

Another question was asked among the same sample frame (N=53), to identify the extent to which knowledge sharing is formally monitored or documented as part of the organisational culture. Responses were much the same with only 5.5 per cent claiming high levels and 50.9 per cent claiming that monitoring and documenting knowledge sharing is done on a low or very low level. These responses reflect that some organisations have some measures in place but would not categorise them as measuring KM. In addition, it implies that developing formal methods for measuring KM in organisations is constrained further by the absence of any monitoring systems. This result corroborates the finding with regard to measuring KM in project-based organisations discussed above.

A CONDUCSIVE CULTURE AND ENVIRONMENT FOR EXPLOITING KNOWLEDGE FOR INNOVATION

The issue of organisational culture is complex. Culture evolves over time and is shaped by internal and external forces that impact on an organisation. The social networks in organisations are an inherent part of the organisational culture and it is necessary to understand and evaluate the types of people and social networks that exist in the participant organisations. KM depends ultimately on people and their commitment to share, transfer and exploit their own knowledge assets. In project-based industries, especially construction, there is a great deal of occupational specialisation. For each project task there is a highly skilled professional to deal with it. Encouraging people to share knowledge and consequently developing a knowledge-sharing and knowledge-creating culture depends on the nature of relationships in organisations. Fundamental to this is the issue of trust. One of the senior managers interviewed noted that through daily informal meetings with employees about day to day issues trust is incrementally built up among the staff. He stressed that trust networks are an essential part of reciprocity among staff and confidence in the organisation. He further noted that "when people begin to have trust in the system you start to get the pay back"

Essentially, knowledge sharing is a cognitive process. Sharing tacit knowledge is a highly personal activity that demands an environment characterised by trust, respect and reciprocity. When individuals engage in the transfer of tacit knowledge, relationships are developed. It is a managerial responsibility to build the right kind of relationships where tacit knowledge exchange adds value to the organisation as a whole. Only then is innovation generated that will lead to competitive advantage. Nonaka and Konno (1998) suggest that innovation can be generated through the development of 'ba', a shared social space that acts as a platform for emerging relationships where individual and collective knowledge is developed. In other words, an organisational culture where the knowledge sharing process becomes embedded and tacit knowledge of individuals can be turned into corporate knowledge and exploited for competitive advantage.

Moreover, it has been asserted that the development of a Community of Practice (COP) in which individuals become members of 'professional families with a strong sense of reciprocity' (Egbu, 2001b), is useful for KM. Informal networking within and across project teams and the organisation is an effective way to share knowledge and generate innovation.

Organisational culture is context specific. However, the study attempted to identify the cultural characteristics of project-based organisations (i.e. construction, aspects of manufacturing, the utilities and aerospace) and the extent to which they impact on key knowledge management issues. The rating scales used are 5= To a very high extent, 4= High, 3= Low, 2= Very low and 1= Not at all. These are also used to compute the mean values. The result is presented in Table 7.1.

Table 7.1: Cultural variables and knowledge management

CULTURAL VARIABLES	**MEAN VALUE (N = 53)**
Use of IT to share knowledge	3.5
Teaching employees their rights and responsibilities	3.3
Recognition of teamwork	3.2
Encouragement to try new work practices	3.1
Cultivation of a learning-by-doing culture	2.9
Ability to share knowledge in training and development	2.8
Encouragement to share ideas about common work practices	2.8
Risk-tolerance	2.8
Identification and implementation of best practices of competitors	2.6
Viewing mistakes as experimentation, rather than attaching blame	2.5
Monitoring and documenting the impact of knowledge sharing	1.7
Measurement of the effects of knowledge sharing	1.7

The higher the mean score, the greater the extent to which the cultural characteristic is perceived to impact upon KM. An inspection of Table 7.1 reveals that the highest mean score relates to the use of IT to share knowledge. This would suggest that organisations are investing more in IT than any other cultural variable. This would appear to be a symptom of a wider issue. Organisations tend to implement tools and technologies to support KM initiatives before implementing a clear and identifiable KM strategy. It is important to stress that KM is not just IT, it encompasses a holistic management philosophy, which should be integrated into the corporate strategy. The author asserts that implementing KM practices that are purely based on IT is less successful than those, which incorporate organisational and people issues. Recognition of teamwork and the cultivation of a learning-by-doing culture are also rated relatively highly.

Unsurprisingly, the lowest scores in the table are with regard to measuring, monitoring and documenting IC and knowledge in an organisation. It is important that organisations begin to give due cognisance to the measurement of KM and IC benefits. It is through this that continuous improvement and organisational renewal can be achieved (Egbu, 2000). It is recommended that the individuals in an organisation be valued, through trust and respect, as this has the potential to encourage tacit knowledge sharing. Valuable knowledge emerges predominantly from the social networks in an organisation and individual creativity should be encouraged through the establishment of a supportive organisational culture. Culture is evolving and cannot be changed quickly or for short-term goals. It is shaped by a number of variables that are context-specific and long-term.

CONCLUSIONS AND RECOMMENDATIONS

This paper has considered the increasing role and importance of knowledge management and intellectual capital for improved innovations and competitive advantage in project-based organisations. The main challenges facing organisations in the exploitation of KM for improved innovations also received some coverage. Organisations are at different stages in the knowledge management implementation trajectory. The effective exploitation of KM depends on many factors, which include people, organisational structure and culture. Organisational culture needs to be nurtured to incorporate the notions of continuous learning, openness, flexibility, the ability to encourage creativity in individuals and establish trust, respect, reciprocity and value systems to support KM.

Innovation depends ultimately, on strategic priorities of project-based organisations. The development of a KM strategy, a supportive organisational structure and culture and the introduction of appropriate IT, will all contribute in some way to the implementation and exploitation of innovation.

The quantitative data reveals that the contribution made by KM on innovation is perceived to be less striking than posited by many researchers. This is largely due to the lack of formal measures of the impact of KM on innovation. It is clear that KM is often associated with the growth of IT in organisations, suggesting that KM should be understood more as a holistic and integrative management philosophy rather than one, which focuses overwhelmingly on IT.

Evidence from the study on which this paper is based also suggests that there is scope for improved awareness of the contribution of KM and IC in construction organisations. There is also very little empirical study on the measurement of the contributions of knowledge management and intellectual capital on incremental and radical innovations in projects and in the wider organisational context. There is therefore ample scope for research in this area for the benefit of the practitioner community.

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INNOVATION THROUGH STANDARDIZATION AND PRE-ASSEMBLY: ISSUES FOR BENEFIT MEASUREMENT

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ABSTRACT

The decision to use standardization and pre-assembly is often not made early enough in the construction design process. Adapting traditional designs at a later stage is clearly inefficient. There is a reluctance among clients and contractors within the construction industry to adopt recent UK government and industry initiatives and employ innovative technologies, because they cannot see the "pay back". This paper describes issues raised within research to develop an interactive toolkit for measuring benefits and locating value in the supply chain, in order to inform the standardization and pre-assembly decision-making process.

The toolkit incorporates a model which evaluates the benefits of using standardization and pre-assembly for construction projects from feasibility, through design and construction, to handover, operation and decommissioning. While some benefits are measurable in monetary or non-monetary terms, other benefits may have a considerable influence on the success of the project or business enterprise, yet are not easily measurable in quantitative terms. Some measures may be obtained directly from project records while others require detailed analysis of project data. Furthermore, there may be a trade-off between an increased cost in one phase of a project and a benefit in another phase or a subsequent project.

The work described forms part of the UK Government funded IMMPREST Research Project (Interactive Model for Measuring Pre-assembly and Standardization Benefit across the Construction Supply Chain).

INTRODUCTION

Recent UK government reports, including the Egan Report "Rethinking Construction" (1998), produced by the Construction Task Force, discuss the need for performance improvements in the UK construction industry and identify supply chain partnerships, and standardization and pre-assembly (S&P) as having roles in improving construction processes. Egan (1998) also notes that the construction industry needs to learn from good practices within other industries, using similar tools and techniques for performance measurement and improvement. The report proposed the creation of the Movement for Innovation (M4I), through which the construction industry has responded to its recommendations.

In this context, research is being undertaken at Loughborough University to develop an interactive toolkit for evaluating benefits, in order to inform the S&P decision-making process and thereafter measure its success. The work described forms part of the IMMPREST Research Project (Interactive Model for Measuring Pre-assembly and Standardisation Benefit across the Construction Supply Chain), which is funded by the UK Government. There is a consortium of collaborating companies from across the UK construction supply chain.

DEFINITIONS

Standardization

Gibb *et al* (1999) define standardization as "the extensive use of processes and components with regularity, repetition and a background of successful practice" and describe the different types of standardization.

- Generic project standardization: international standards, e.g. ISO 9000,
- National standardization: standards within a country or group of countries,
- Client standardization: standard elements, processes or procedures specified by a particular client, e.g. corporate logos, contractual practices,
- Supplier standardization: standard components, sub-assemblies or products specified by a supplier or entire industry sector,
- Project standardization: the decision by a project team to use standard procedures or components for a particular project.

Pre-assembly

Gibb *et al* (1999) and Gibb (2000) describe the various types of pre-assembly.

- Pre-assembled components and sub-assemblies: e.g. window frames or complete windows, including glazing and ironmongery,
- Non-volumetric pre-assembly: pre-assembled units that do not create usable space, e.g. building services ductwork or cladding,
- Volumetric pre-assembly: pre-assembled units that create usable space and are usually fully factory-finished internally, e.g. toilet pods, plant rooms or modular lift shafts,
- Modular building: a building comprising one or more volumetric units which form the actual structure and fabric of the building, e.g. motels or classrooms.

Terms used synonymously with pre-assembly include "prefabrication", "off-site fabrication" and "off-site manufacture". "Modularization" embraces concepts used in both pre-assembly and standardization.

BENEFIT

In a toolkit for evaluating the benefits of standard processes, standard components and pre-assembly, Gibb (2000) uses the concept of three categories of benefit, as developed in Construct IT (1998):

- Efficiency – benefits which are financially measurable, e.g. by use of cost records, time sheets,
- Effectiveness – benefits which are measurable but not always in monetary terms, e.g. greater certainty of cost and time estimating,
- Performance – benefits which have an influence on the outcomes of a project or business enterprise but are not easily measurable in quantitative terms, e.g. better working relationships, improved health and safety.
- A second concept of benefit measurement, identified during the data collection process, is the directness of the measure. Some data for evaluating benefits can be obtained directly from sources such as cost

records, project time records, material costs and direct human resource costs. Other data may be obtainable, but only after detailed analysis of project data which may delay the decision-making process. Other data may exist in an incomplete form; for example, records of time lost because of accidents give only a partial evaluation of the health and safety benefit.

The term "benefit" implies an increase in efficiency, effectiveness or performance. The use of S&P for some elements of a construction project may produce decreases in efficiency, effectiveness or performance, this is termed a "disbenefit". A benefit in one phase of a construction project may give rise to a disbenefit in a later phase. Conversely, a disbenefit in one phase of a construction project may produce a benefit in a later phase of the same project, or in a future project.

There is a need to develop robust measurement techniques, which will allow evaluation of the effect of these trade-offs. There is also a need to evaluate any perceived detrimental effect which represents a barrier to the use of S&P.

RESEARCH DESIGN AND METHODOLOGY

Research aim and objectives

The aim of this research is to investigate methods for measuring and comparing the benefits of S&P against traditional construction, in order to develop a robust evaluation model for informing the S&P decision-making process.

The objectives are to identify the benefit factors that need to be considered in such an evaluation, the data required for assessing the effect of these factors and the location of the required data within the supply chain. The research will also identify and evaluate tools and techniques for measuring the benefits of different construction processes. For "performance" benefits which are not measurable in quantitative terms, the research is investigating the performance measurement tools and techniques used in construction and other industries.

Methodology

The early research involved a survey of previous studies on applications of S&P, including the successful pilot study at Loughborough University, COMPREST (Cost Model for Pre-assembly and Standardization), which investigated the S&P design and construction processes within the mechanical services sector.

Literature on performance measurement and analytical techniques used in construction and in wider business and management disciplines is being reviewed; this includes documents and presentations on benchmarking and key performance indicators produced as a result of UK government initiatives.

Primary research data is being obtained from collaborating companies, using case studies and questionnaire surveys to investigate perceptions of how and where in the supply chain benefit accrues, and for whom it is a benefit.

BENEFIT FACTORS

In addition to the COMPREST pilot study, described above, other research has identified factors which describe the benefits and disbenefits from using standard procedures, standard processes or pre-assembly. This includes the MEDIC (Modular Engineering Design Integrated Construction) research project at Nottingham University, UK. Publications which identify benefit factors include Neale *et al* (1993), Gibb (1999, 2000), Gibb *et al* (1999), Wilson *et al* (1999) and Gibb and Isack (2001). The benefits cited by interviewees are not the same in all research exercises, because different construction projects have different priorities. For this reason, any benefit measurement model needs to include the flexibility for construction personnel to specify their own priorities.

Benefit factors identified by the research described above can be grouped together to assist with identifying the appropriate measurement technique, as in Table 1. Where a factor could be categorized under more than one heading, care must be taken to ensure that there is no double counting when evaluating the benefit. The list is intended to be illustrative and is not exhaustive.

Table 1 Benefits of using Standardisation and Pre-assembly

Cost	Efficiency	Reductions in: total project costs, overheads and preliminaries costs, in-house costs and fees, component design and production costs.
	Performance	Better value (better solution for the same cost).
Time	Efficiency	Reductions in: overall project time, design time, construction period, commissioning period, on-site time, site and other management time.
	Effectiveness	Reduction in delivery lead times. Off-the-shelf availability of components.
People	Efficiency	Greater efficiency, smaller project teams, fewer people on-site, fewer claims.
	Performance	Better teamworking, transfer of knowledge to subsequent projects, clarity of roles and responsibilities. Input to the design process by the manufacturer, greater understanding by the client.
Risk	Effectiveness	Reduced financial risk because of greater certainty of cost and time estimating and completion date. Reduced on-site storage.
	Performance	Reduced risk, evaluated qualitatively when hard data are not available.
Quality	Efficiency	Consistent quality of components and reduced need for quality assurance checks.
	Effectiveness	Better quality of final project, fewer defects. Better interfaces between components.
	Performance	Facility for off-site quality checks, earlier on-site weatherproofing, less snagging.
Health and safety	Effectiveness	Increased site safety, fewer on-site accidents.
	Performance	Improved off-site working environment.
Environment	Efficiency	Reduced energy use, transport, waste, site damage.
Beneficial processes/ operations	Effectiveness	Simplification of construction process, better planning of work schedules and less disruption.
	Performance	Increased facility to reproduce projects, centrally driven processes, easier maintenance, secure supply chain, easier integration of design.
Detrimental processes/ operations	Efficiency	Cost of setting up manufacturing facility, extra stage in supply chain, additional logistics costs in storage and handling of larger units.
	Performance	Perceived lack of flexibility by client, difficulty in conforming to urban planning requirements.

DATA COLLECTION AND MODEL DEVELOPMENT

Pasquire and Gibb (1999) note that the decisions to use S&P are still based on anecdotal evidence rather than rigorous data as there are no formal measurement procedures or strategies available. The COMPREST pilot study highlighted the poor availability of cost information and the need for improved data collection procedures. A major element of the research is therefore the collection of project data.

Data for mechanical and electrical services is being collected on major UK construction projects, including airports and city centre office complexes, with the project's collaborating partners and other companies across their supply chains. Projects using S&P are compared with those using traditional methods. Additional data was collected at a research workshop for industry stakeholders.

The IMMPREST research project uses the collected data and the measurement techniques described in this paper to develop a database and a benefit evaluation model to identify which individual techniques or combinations of techniques are most appropriate for the analysis of specific scenarios. The benefit measurement model includes the flexibility for construction clients and contractors to specify their own priorities. The model does not include detailed cost data which would be commercially sensitive and would require constant updating.

TOOLS AND TECHNIQUES

Cost

While cost records are available for measuring cost efficiency benefits, value management techniques enable improved cost performance, i.e. greater added value, to be achieved and measured. Ashworth and Hogg (2000) describe value management as comprising value planning, in the earliest stages of a project, value engineering, in the detailed design and construction phases, and value analysis, following the completion of a project. Evaluation techniques used in value management include life cycle costing, which takes account of costs in use as well as during design and construction, and functional analysis system technique (FAST).

Ding (1999) describes the technique of Economic Cost-Benefit Analysis (CBA) to evaluate alternative options in construction projects, with the use of net present value (NPV) to measure financial benefits and resource costs over time. She explains the use of multiple criteria decision making (MCDM) which applies weights and scores, rather than financial measures to evaluate project options.

Benchmarking and key performance indicators

Ashworth and Hogg (2000) and Rossiter (1996) both note the importance of benchmarking in improving the performance of the construction industry. While Rossiter (1996) defines of benchmarking as a process of collecting data for comparing companies, he also states that it can be used to compare operations or functions within a company. The essence of benchmarking is that it uses key performance indicators to evaluate processes. Similar techniques can be used to evaluate the benefits of S&P by comparing operations with those of traditional construction methods. A report from the Construction Industry Research and Information Association (CIRIA, 1998) recommends the wider use of benchmarking in construction.

A report on the use of key performance indicators (KPIs) from the KPI Working Group of the UK Department of the Environment, Transport and the Regions (DETR, 1999) describes measures of performance for construction within seven main groups. These are summarized in Table 2. The report gives examples of KPI calculations, some involving monetary or other quantitative calculations and others involving weighted or normalized scores.

The M4I Working Group on Respect for People (DETR, 2000) has developed a set of toolkits with checklists and scorecards which are being trialled within companies and on projects to produce benchmarking performance data.

Christopher (1998) describes the use of logistics performance indicators for benchmarking the logistics and supply chain processes; his three key performance measures are quality of service, i.e. order achievement, time and cost.

Table 2 Key performance indicators

Time	Time for construction, time predictability, time to rectify defects
Cost	Cost for construction, cost predictability, cost of rectifying defects, cost in use
Quality	Defects, quality issues on handover
Client satisfaction	Client satisfaction, including client specified criteria
Client changes	Change orders by client or product manager
Business performance	Financial and other measures of performance by the company or project
Health and safety	Accidents and fatalities

Time

Reductions in time at different stages of a project give rise to efficiency benefits measurable in terms of human resource costs, equipment hire costs etc. which are classified under other factors. However, time reductions in one operation will not reduce the overall project time unless that operation is on the critical path. Christopher (1998) describes techniques in strategic lead-time management which allow the benefits of reduced delivery lead times to be evaluated.

People

While some human resource benefit factors can be directly measured using time sheets and personnel records, other factors are less easily measurable. The M4I toolkits (DETR, 2000) include measures for employee satisfaction, staff turnover, absence from work, safety, working hours, training and development and pay. The relevant toolkits are: Off-Site Working Environment, Career Development and Lifelong Learning, and Diversity in the Workplace.

The discussion of teamworking and partnership across the construction supply chain is developed in many texts, including Bennett and Jayes (1995) and Cornick and Mather (1999). Holti *et al* (2000) describe the role of cross-functional teams in managing project costs.

Risk

Risk assessment is covered by many texts including Smith (1999) and Koller (1999). Measurement of risk is obtained from a combination of impact and likelihood. Where hard data are available, this measure may be calculated as:

Value of risk = Monetary value of outcome x probability of outcome (%) (1)

Monte Carlo analyses and decision trees may be used to evaluate the risk where there are multiple options. Sensitivity analysis is a quantitative technique for exploring the effects of economic changes on a project. Where hard data are not available, impact and likelihood may be measured on a multi-point scale, very low, low, … high, very high, and combined to produce a composite score.

Processes and operations

The CALIBRE toolkits, developed by the UK Building Research Establishment, measure and classify construction activities as Added Value, Non Added-Value, Support or Statutory to enable non added-value time to be identified and reduced or eliminated.

Following on from various texts on lean thinking in other industries, Flanagan *et al* (1998) describe the application of lean principles to construction. Their four steps to achieving lean design and three steps to achieving lean supply, summarized below, include the use of S&P, as in other lean production environments.

Table 3 Lean principles in construction

Four steps to achieving lean design:	Three steps to achieving lean supply:
Focus on design	Process improvement
Maintain customer focus	Use technology to support the reengineered process
Eliminate non value-adding processes	Managing supplier relationships
Focus on the supply chain	

Quality

Baxendale (1997) observes that quality costs comprise prevention costs, appraisal costs, internal failure costs and external failure costs. The costs involved in the first three of these, e.g. maintenance, inspection, reworking, wastage, can be identified and directly measured. Some external failure costs may be identified and measured, e.g. correction of errors, repairs, replacement of faulty materials and litigation; these are the known effects of customer dissatisfaction. There may also be unknown and unknowable effects of customer dissatisfaction, e.g. future lost business.

The principles of total quality management (TQM) include continuous improvement in quality, reliability and customer satisfaction by examining and improving processes, rather than results. The use of S&P can be treated as an example of process improvement.

Health and safety

The M4I toolkits (DETR, 2000) include measures for occupational health and safety. The relevant toolkits are: Health and Safety in Procurement and Design, Health, Site Safety, On-Site Welfare, and Off-Site Working Environment.

Environment

Wathey and O'Reilly (2000) describe the international standard for environmental performance evaluation (ISO14031) and the performance indicators which may be used to evaluate the financial and non-financial environmental impacts of a project or enterprise.

FURTHER RESEARCH PROPOSED

Further collection of data for mechanical and electrical services is being carried out by trialling a paper version of the model on case studies with the project's collaborating partners and other companies. The research will then be extended from the Mechanical and Electrical Services sectors to Frame, Envelope and Internal works.

To develop the model further, the research will use interviews and questionnaires to investigate how and when the model is used. The model will be evaluated by industry stakeholders at a second research workshop, The model will be made available to collaborators electronically and also via a restricted access area of the project website, www.immprest.com

An iterative process, such as the Delphi method, will be used to refine the model. The refined model will be published and disseminated using a CD-ROM, which can be used to assist decision-making by estimating the potential benefit of future S&P applications.

CONCLUSION

The research work being undertaken aims to produce an interactive toolkit to assist the standardization and pre-assembly decision-making process. The value of this research is in identifying and employing techniques for evaluating opportunities to use innovative procedures and products which will increase the efficiency and competitiveness of construction clients and contractors. It makes an important contribution to the agenda for improved construction performance set out in the Egan Report (1998).

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Management Innovation In The Danish Construction Sector

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INTRODUCTION

The Danish construction sector has been marked the later years by a debate, fuelled by several public investigations, on the disappointing development of productivity in the sector. One of the identified reasons for this is the difficulty within the sector with innovating management and organisation (Byggepolitisk task force 2000). A recent survey on excellence in management, based on CEO-s answers to questionnaire thus shows construction as the poorest managed sector in terms of results, systems, human resources and management (Dansk excellence index 2001).

This paper proposes to develop a specific focus on management innovation. The assumption is that although management innovation share features with innovation in general, management innovations share special features in terms of content, the journey (or diffusion) and the barriers for appropriation. There is a specific focus on commodified management innovations, concepts such as Business Process Reengineering and Knowledge Management. The paper presents an understanding of the content and novelty of such packaged management innovations and three perspectives on the travel of the innovation; the neoinstitutional, the knowledge transfer and the social shaping. The paper concludes that it is the social shaping perspective that provides the most promising conceptualising of the journey of management innovations. According to this perspective management innovations should be regarded as change programs or political programs, and negotiation processes, forming alliances around the innovation, is seen as crucial. Cases of management innovation are then presented distinguishing two types. Type 1 is "readymade"-concepts from other sectors which is appropriated by firms and type 2 is sector appropriation over longer time and innovating across companies. Barriers and actor coalitions around the innovations are discussed and it is concluded that management innovation does have specific features that justify a more specific focus in the future.

METHOD

The paper is explorative in character. It builds on previous studies about management concepts in manufacturing (Koch et al, 1997, Heusinkfeld et al, 1999). This material is combined with theoretical perspectives from innovation studies such as innovation economics and social constructivism. The concepts and frames are applied to construction and especially construction management.

The paper does not present a systematic meso or macro study of management innovation in construction sector. It uses material on the macro and meso development in combination with (micro) case studies of management innovations in construction firms (Koch 2001a,b). Moreover it builds on master thesis and students reports in the Danish Technological Uuniversity (DTU)-course "new production concepts in construction". The knowledge management case is thus drawing on Bellouki (2001), and Simonsen (forthcoming). The description and analysis of the multiskilled teams are in two cases built on reports from experiments done under the auspices of the ministry of housing and in one case on dialogues with actors involved in a currently running experiment with multiskilling. The cases have been chosen because of the richness of their material.

MANAGEMENT INNOVATION

Innovation is, since Schumpeter, often defined as developing and implementing a new idea (Van de Ven et al 1999). The content of "idea" is qualified by splitting it up in product and process innovation, or in product, program and service- versus administrative innovations (Van de Ven et al 1999, Clark & Staunton 1989). As Clark and Staunton notes there has been a clear tendency to black box innovation into technological equipment, technological products (artefacts) or other technologies. Nevertheless the concept has gradually opened up, as the understanding of innovation, and its role in developing enterprise, develops. In construction it is equally clear, that there is a tendency towards more and more focus on process innovation. (Bang et al 2000). Moreover Van de Ven et al divides the administrative innovations into new procedures, policies and organisational forms. Given the above introductory characteristic of management in Danish construction, there seems to be a need to conceptualise management innovation as a distinct part of innovation. This conceptualisation is needed to focus the efforts on management within construction. Management innovation is thus defined as developing and implementing new ideas in managerial activities and support systems. Managerial activities encompass assignment of tasks, coordination, communication but also issues like leadership and style. The support systems for management are IT, organisation and human resources. Thus management innovation overlap with innovation in its traditional conceptualisation.

The content of a management innovation

Management innovations might grow up from inside in a construction company. It might continue to reside in such a context. There is however a very clear tendency to adopt packaged and even commodified management ideas and those are the focus here. Commodified management ideas or concepts include such as CRM, BPR and TQM. They are perhaps the most elaborate and explicit management innovations. A critical reading of management concepts aids us in understanding the content of management innovation as such. Huczinsky (1993) and Grint (1995) argue that a management concept usually contains theory, some experiences that are made abstract and general. A concept contains a diagnosis of problems and some suggestions for solutions. Furthermore, it contains methods for analysis and suggestions for the management of change. More implicitly the concept contains a view on man and organisation. Finally, some practical experience is obligatory. The political program might relay on a long-term vision, when forwarding short-term change (Grint, 1995). Summarising these characteristics we have formulated a frame for understanding a change program, a management concept in the following bullet points (Koch et al 1997):

- Main definition
- Problcmdiagnosis
- Scope
- Understanding of man and organisation
- Procedures
- Results

As Winch (1998) rightly point out criticising innovations in general, the majority of them are developed to fit with mass-producing companies in manufacturing or service. They thus usually need appropriation for most construction companies even in the core of the idea. Appropriation terms profound implementation of an innovation with accompanying change of the innovation itself and the surrounding organisation (Clark & Staunton 1989, see also Fleck 1991). The novelty of a management idea can always be discussed and it is quite often a rebundling of existing ideas. Moreover novelty is relative to time and context and that some construction firms might need to appropriate an idea quite heavily even though it is well developed and stabilised within manufacturing.

THE JOURNEY OF MANAGEMENT INNOVATIONS: THREE PERSPECTIVES

Although the linear model of innovation diffusion is still prevalent, in for example state policy proposals, the last ten years interest in innovation and its spread has developed other understandings of the journey (Van de Ven 1999). There is today a well under pinned body of works arguing for other understandings (Fleck 1991 and many others). Moreover there has been a separate interest in the spread of management ideas drawing on neoinstitutionalism, social shaping and knowledge transfer perspectives. The focus for all these positions has been the packaged commodified management ideas, or concepts.

The neoinstitutional perspective

The neoinstitutionalist perspective is by far the most developed and widespread of the two perspectives on management concepts discussed here. Numerous books and articles discuss the dynamics of management recipes, ideas or discourse as examples of the isomorphism which is the central thesis of neoistitutionalism (Scott & Meyer 1994). The main observation within the neoinstitutionalism have been summarised by Scott & Meyer (p34):

"Overall the institutional image of modern organisational life suggests organisations that are; a. Somewhat ritualised, b. Internally decoupled, c. Isomorphic with environmental patterns and rules in their identities, structures and activities, and d. Broadly showing isomorphic patterns of change over time"

The studies of management concepts encompass a broad spectre of concepts and national and international contexts (Abrahamson 1996, Abrahamson & Fairchild 1999, Røvik 1998 and others). Central to the majority of these studies is the assumptions of stability of the recipe which is spread. The perspective typically understand the process through literature studies where the number of articles and books published on a subject is taken to be a proper description of the process the concept is "running through" over time (see Røvik 1998 and Abrahamson & Fairchild 1999). Variants of the concept are not discussed. Rather these are either taken for granted or the variants not understood as important enough. Røvik 1998 notes that there can occur differences in the content of concepts but

" A literature review will quickly reveal a bundle of elements which is recurring in most contributions and which can be claimed to be the core of the concept" (p55)

This common content is then used as basis for counting articles and representing the process as a bell shaped curve, a cycle. The contents of the concepts are the substance that the organisational actors will mimic as part of the building of isomorphism. The content is thus understood as symbolic and ritually oriented, although terms like knowledge producers and knowledge consumers are used to describe concept originators and receivers. Neoinstitutionalists thus characteristically understand the journey dynamics as far from rationalistic. The role of the actors is downplayed, since the social authorisation (Røvik 1998), the rites and symbols have strength to "break" through which goes beyond conscious choices of rational actors. In the neoinstitutionalist perspective, the dynamics of ever more concepts is seen as a part of the process towards isomorphism. This is seen as a discourse like dynamic, where development of rhetoric is central.

The Knowledge Transfer perspective

With the increasing focus on learning, knowledge, competencies and management of knowledge, the acquisition of necessary knowledge, the transfer, has become a topic for a number of contributions (Nonaka &Takeuchi 1995 and others). The main observation within the knowledge transfer perspective is that contemporary organisations need to acquire knowledge from external sources in order to survive in an information society. Although management concepts as vehicle for the transfer are not frequently discussed, the perspective does occur. Van Veen, Karsten & Sanders 1997 thus discuss management concepts as tools for knowledge transfer drawing on Nonaka & Takeuchi-s framework for understanding the production of knowledge. Van Veen et al distinguish between knowledge producers and knowledge copiers, as it is also often done within neoinstitutionalist studies. Knowledge producers, argue Van Veen et al, are the enterprises within which the knowledge in the management concept is created. The knowledge is then externalised and made accessible for others in various ways, in books, via management consultants etc. The knowledge copying is the internalisation process in Nonakas & Takeuchis' framework. This is when a company adopt the management concept. Where neoinstitutionalists are sceptical towards the content of and rationality of the knowledge, the knowledge transfer- position are often rather uncritical towards the potential political, symbolic or ritual character of the concepts. Moreover the position seems to have a strong belief in the stability of the concept and the actors ability to make strategic choices in taking knowledge onboard. In the knowledge transfer perspective new economic demands forces enterprises to be more competent in transferring new knowledge, which is seen as crucial for competitiveness.

The social shaping perspective

The content of a concept has a striking overlap with Kuhns notion of "paradigm", which he uses to describe the development of scientific knowledge and communities. Therefore the sociology of scientific knowledge, social shaping and social constructivism has been mobilised to conceptualise the phenomenon of management concepts. The sociology of scientific knowledge after Kuhn has moved to the direction of studying how scientific knowledge is socially constructed. Although the focus is on scientific knowledge, the contention is that knowledge in general is not different (Collins 1990). Moreover the interest is on how actors collectively work at stabilising fact through negotiation, coalitions and enrolment of others. Studies of management concepts (Grint 1985, Furusten 1996) within social constructivism are however still rather diverse in their understanding. The main observation within a combined organisational politics and sociology of knowledge perspective is however that management concepts are socially constructed and negotiated. To stabilise a concept coalitions and alliances is needed across the boundaries of an organisation. Another strand adopt organisational politics as point of departure. Within organisational political a new management idea is a political programme (Koch et al 1997). The political programme is shaped in interaction between different actors, building alliances and overcoming barriers and resistance. When actors enrol in the alliance the content of the concept usually changes. Within the political process perspective as described here, the dynamics of ever more concepts in a continual stream is seen as socially constructed. The main actors behind this are the consultancy companies, for whom the concepts are commodities to be sold. New concepts are in this context product development. On the other hand the enterprises also have a certain room for manoeuvre in order to develop their organisation in the direction that contemporary is believed to be more competitive.

Summarising the perspectives, there are examples of clear differences between them. A management innovation and it process of travelling can be understood as frictionless transfer of stable knowledge or as a political program that needs to be negotiated and which will change over time in this process of making alliances. As the perspectives are different it should be noted that there also exists a number of eclectic oriented mingled versions. It can be mentioned moreover that the literature on innovation network increasingly adopts views across these three positions. There is often a resonance between the content and direction of a management innovation and a certain group of managers or a managerial position, professional gurus and professional networks (Swan et al 2001). Several authors have noted a tendency of Zigzag in the sequence of implemented management innovations (Midler 1986).

THE DANISH CONSTRUCTION SECTOR

The development arena (Jørgensen and Sørensen 1999) in question here is the Danish construction sector. The actors represented are roughly the same as in other national construction sectors. A relatively active state and a high proportion of organised labour can be seen however as a national characteristic. It should be mentioned that three large contractor companies by now dominate contracting and equally three large civil engineering companies dominate consultancy and design in construction.

There is moreover very little research and development in construction management methods in DK at the public research institutes, that goes for university research, sector specific applied research and technological service institutes (Bygge/bolig 2000, Byggepolitisk taskforce 2000: 143).

Management innovation in construction can be divided into two groups with different journeys and dynamics. One group of innovation target areas of construction, where the companies, with the usual appropriation efforts, can adopt general management innovations. This type is labelled, optimistically, “here and now buy in” below. Examples could be large construction companies, contractors or civil engineering companies adopting balanced scorecard or strategic planning. Another group of management innovation needs more fundamental reconfiguration by sectoral actors before being applicable. Examples could be multi-skilled teams on the building site, Business Process Reengineering cutting across several parties and the transition from lean production to lean construction.

Type 1: Here and now ”buy-in”

Most of the exemplars of this kind of management innovation in Danish construction is single enterprise change. Among the larger Danish construction firms, there are thus examples of appropriation of Balanced Scorecard, Enterprise Resource Planning, Human Resource Management and Supply Chain Management. All these innovations have been developed in another context, typically on an US-development arena with enterprises, consultancy and universities participating. The innovations are however conceptualised in such a general way that they would apply and appeal directly to larger construction firms. It thus seems to be a pattern that the big six (3 contractors and 3 civil engineering consultancies) usually are first movers in introducing a management innovation. This is also the case in the example below about Knowledge management.

Type 1 Case: Knowledge Management

There are from the very start several origins for the ideas on knowledge management (KM)(Swan et al 2001) and the ideas develop over time throughout the nineties. The IT- sector and related actors discuss knowledge engineering in the eighties and this is in the nineties gradually developed into an understanding of IT as central in managing knowledge. The Porter’s discourse on strategic advantage in management fuels the core competency discourse (Hamel & Prahalad, 1990), which again contribute to learning and creating knowledge positions (especially Nonaka in 1994 and later). Finally the economists discourse on Intellectual Capital (OECD, Mortensen 2000) and knowledge accounting contributes. As Swan et al demonstrate the boom in literature commences in 1996 and continues to have ambiguous content and be characterised by "hyperactive supply side" comprising all the major consultancy companies in promoting-alliance with IT-suppliers of KM systems. Early Danish construction adopters include Rambøll. Rambøll starts developing holistic accounting in the early nineties, which is an appropriation of the European Quality Award model, which again stems from total quality management (Erhvervsfremmestyrelsen 1997). Also but later Carl Bro and COWI adopt the strategy of human capital accounting. It is likely that this company appropriate human capital accounting because an alliance and a "must do" imperative are built up. All of the three possess management consultancy competencies and COWI has added a public project on knowledge accounting in the late nineties (in contrast to Rambøll who contributes to the public program already in 1997. In parallel to this is likely that the trade association FRI (association of consulting engineers) acts as disseminator of the IT/management oriented variant of KM with its activities on the subject in 1996-1997 (Bertelsen, 1996). The information from Danish media and professional association activities on the subject covers the period from 1998-99 and 2000. In this period, first the IT-based and later the management-based variants of KM flourished. Medium size civil engineering companies such as Birch & Krogboe and NIRAS have by 2001 adopted and appropriated Knowledge management in its latest variant. Several case studies carried out by the author and his associates demonstrate some of the characteristics of the single company appropriation (Koch 2001 a,b). The innovation is "let into" the organisation at the firm level, not at the project level, as many product innovations are (Winch 1998). The appropriation is a cumbersome process, the enterprises struggle with tensions in management (for example between HR- and KM-managers), getting IT-support for knowledge sharing in place and have problems embedding the innovation in the project processes. When implementing the innovation, project groups was formed and in this process the changes was negotiated and the innovation appropriated to the specific context. Examples of appropriations include whether or not to reward use of Intranet information resources, whether or not to have knowledge managers and with what profile and what parameters to include in the knowledge accounting. As it can be noted, public debate, international consultancy companies, internal consultancy departments, state development programs and a trade association for consulting engineers all play a role in the journey of the concept. All of these, except the last, operate across sectors and are not construction specific actors. The innovation "knowledge management" is characterised by continual development and by the existence of several variants, which coexists. There is thus a continual interaction between what the companies do and what the fashion promotes.

Type 2: Long Term sector appropriation

Most of the exemplars of this kind of management innovation in Danish construction is crosscutting innovations, which targets what Gann coins one of the "ghosts" of construction: the cooperation among and across the parties (Gann, 2000:5). Among the larger Danish construction firms, there are examples of appropriation of Partnering, Lean Construction, Multiskilled teams and Business Process Reengineering. These innovations have been developed on the construction sector development arena, typically drawing on an international construction development arena with enterprises, consultancy and universities participating. That the innovations originally stem from other sectors is less important since it is through the "internal construction" development that they gets (re-) conceptualised in such a way that they would apply and appeal directly to construction firms. Business Process Reengineering is thus developed in a program and project coalition within the state development program called "process and product development" (Erhvervsfremmestyrelsen, 2001). Lean construction has been "imported" to Denmark by NIRAS, an engineering consultancy company drawing on international experiences (Bertelsen, 2001). Partnering is in 2001 promoted by the contractor-employers association (Danske Entreprenører) and by several other central actors including one of the three largest contractors, NCC. This however is a result of a long process. Below multiskilled teams are discussed as exemplar of type 2 management innovation.

Type 2 Case : Multiskilled teams

Semi-autonomous teams have a long tradition in construction itself in the shape of teams of craftsmen. It is on this background and on the corresponding contracting-structure as well as employment contract structures that one might find the reason why multiskilled teams is not that prevalent in Danish construction. Teams as such, have flourished several times in other sectors, such as manufacturing and IT. The classical variant is the semi-autonomous groups building on the socio-technical and quality of work life tradition (Eijnatten 1993). Around 1990 the Japanese production principles introduced a series of management innovation were (another variant of) teams were one of them. The literature often distinguish these two as strong and weak teams, since the former is associated with a substantial withdrawal of management, with upskilling and autonomy. The latter on the other hand represents a team which is without these characteristic, but do have common planning and share tasks (Koch & Buhl 2001). Although the process is definitely not free of friction, teams is today a relatively well embedded innovation in the leading Danish manufacturing companies, and covering 22 % of manufacturing firms in Denmark (Csonka 2000). Multiskilled teams in construction are a management innovation which has been under way for quite some years (Burieson et al 1998, Haas et al 2001). In construction the original team innovation has been reshaped into a form of organisation which encompasses task solving across crafts in combination with some co-determination in management decisions such as fine-scheduling. Multiskilled teams are reported to be feasible on market conditions (Burieson et al, 1998).

In Danish construction however, teams continue to exist only as subsidised demonstrations projects (Boligministeriet, 1997, 1999, Byggepolitisk task force 2000). Moreover the concepts has predominantly been used for specialised contracts such as renovation/ urban renewal. And some actors on the arena would prefer to see the concept contained into a speciality for urban renewal or the like. The employment contract system that relates to crafts and to piece-rate, is a surmountable barrier if multiskilling is to be established as a development project. Under such conditions special negotiations with unions can be carried out securing that wage and contract systems are not hindering the new organisation. However in a clean market situation this is maybe more problematic.

CONCLUSION

There is an urgent need for an increased focus on management innovation in construction. This paper has proposed to develop this as specific focus, departing from the assumption that management innovation did differ from other innovations in their content, in the network of promoting actors and barriers to be overcome. Three perspectives on the travel of management innovation were initially presented. Through the cases it has been illustrated how the content of a management innovation is unstable and negotiated. The social shaping, political process and the network perspective therefore seem more promising as conceptual frame around the journey of management innovation rather than traditional innovation economic and management oriented studies. Also neoinstitutionalism "struggles" with a too strong focus on stability of the content and the understanding of publications/rhetoric as the centre of an innovation. The explorative cases presented show how management innovation is special in terms of its macro actor coalition. In the type 1 "here and now buy in"- management innovation, international consultancy companies, internal consultancy departments, state development programs and a trade association for consulting engineers, all of them play a role in the journey of the innovation "Knowledge management". All of these, except the last, operate across sectors and are not construction specific actors. Moreover none of these would be active in for example product innovation, that would be other programs. The type 1 innovation is let into the organisation at the firm level, not the project level as many product innovations are (Winch, 1998). This travel route constitutes specific but classical internal barriers since top- management initiatives frequently have problems with embedding innovations in the projects (Winch, 1998). In contrast, some of the type 2 innovations might be introduced through projects as part of the bidding conditions. Nevertheless multiskilled teams did not yet came further than the subsidised demonstration projects and still cannot be said to have been appropriated in Danish Construction. The actor coalition consists of the state in two roles as promoter of industrial development in construction and as responsible for urban renewal and thereby builder. Barriers include first the institutional split between the players, which implies that it is necessary to establish and maintain cooperation across them. Second the contracting system and the employment contract system. All barriers which to some extent are different from those in a product innovation setting with respect to the players and the actor coalition.

The case studies have shown companies struggling with appropriating management innovations and how they occasionally successfully reconfigure the concepts as long as they are internally used. The type 2 case opens up for an analysis of barriers related to the development arena as such. There are clearly permanent inter-organisatoric collaboration issues, but it can also be underlined that the innovations system seems to be characterised by the very little construction management research and development. This is under scrutiny and there is a belief in a R&D-push created by public investment in knowledge and innovation in general and more specifically also in management research (Taskforce 2000). Along with Gann, pointing at a feature of the type 1 case, it should be noted that the absorptive capacity of construction firms of academically grounded innovation is not indefinite. As stated in Gann, the case underlines the importance of an internal infrastructure in the firms, which should mobilise such innovations. It could in a more speculative manner be observed that there is a need to build a community of practice among the participants in the construction development arena to aid the appropriating of innovation. Current initiatives by universities to offer masters in construction management might be helpful. But barriers have to be overcome in a sector marked by competition and temporary alliances. Another central issue resides in the direction to chose to engage the effort: should it be towards appropriation of generally available management concepts and/or to endeavour into building development arenas, which are more internal in the sector. In management innovation there is hardly any choice: the commodified concepts will be the dominant form in the years to come.

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Implementing Change: New Management Initiatives and their Impact on Company Practices

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ABSTRACT

Despite the proliferation, in recent years, of new management initiatives in the UK and other construction industries, very little research attention has been directed towards understanding the mechanisms and processes by which such initiatives are implemented. This paper reports on research in the UK designed specifically to focus upon the challenges of implementation and the problems of attempting to diffuse knowledge about new ways of working throughout the construction firm. The paper presents a discussion of the factors likely to influence the management of change within the construction firm and reports on the early stages of a research project designed to investigate the impact of new management initiatives within the construction firm.

INTRODUCTION

A host of new management initiatives have emerged in recent years in the UK and other construction industries world-wide, in response to increasing client demands for the more effective construction and delivery of new buildings. These initiatives, which include partnering, supply chain management, benchmarking and value management, are very diverse. However, they share in common the idea that construction companies need to examine and if necessary adapt their ways of working – their business processes and cultures – if they are to respond effectively to competitive pressures.

Despite the extent of change, however, there remain significant gaps in our understanding of the issues involved in implementing new practices and in effecting cultural change. This is partly due to the inherent complexity of the concept of organisational culture, but also due to the problems of sustaining change by capturing and diffusing knowledge and learning from one project to the next. Importantly too, the human resource management implications of change and the effects of change management processes themselves often tend to get overlooked. There is therefore a pressing need for research that systematically examines the factors affecting the adoption and implementation of new ways of working and the improvement of associated knowledge management and organisational learning capabilities.

This paper reports on ongoing research funded by the UK's Engineering and Physical Sciences Research Council (grant reference GR/R12831), which is concerned specifically with identifying and examining the factors influencing culture change and knowledge management practices across a range of related management initiatives in construction. The paper outlines the conceptual framework guiding the research and the methodology to be employed. The research sets out to explore the nature of change processes in contractors of different size (small as well as large), as well as firms engaged in different types of activity (e.g. building and engineering). The paper highlights some of the factors likely to encourage and inhibit knowledge management and culture change strategies needed to implement new management initiatives. It also draws out some of the likely key implications for human resource management strategies within the construction firm.

BACKGROUND TO THE RESEARCH

Radical change in the way in which the construction industry develops and delivers its products and services has been the theme running through recent agenda-setting reports in the UK such as *Constructing the team* (Latham, 1994) and *Rethinking construction* (Construction Task Force, 1998). Taking its lead from recent advances in manufacturing management best practice, the Egan Report, for example, calls for improvements in quality and efficiency by the creation of more integrated project processes of product development, project implementation, partnering in the supply chain and production of components. A similar determination to encourage more efficient, effective and integrated project processes in construction is found in other recent initiatives, notably the Movement for Innovation (M^4I), sponsored by the Department of the Environment, Transport and the Regions (DETR), and the Engineering and Physical Sciences Research Council's (EPSRC) Innovative Manufacturing Initiative.

The result has been a host of industry initiatives that have developed in recent years that have sought to provide the means whereby construction firms can rise to the challenge of becoming more innovative and responsive to client needs and produce better quality products more efficiently and effectively. These initiatives include: partnering and integrated supply chain management; standardisation of products and processes; the greater use of IT applications to support project management; benchmarking and continuous improvement programmes; value engineering, value management and risk management; and various internal cultural initiatives such as business process re-engineering and team-building. The extent of these initiatives is reflected in the wide range of on-going activities associated with programmes such as the Construction Best Practice Programme (DETR), the Construction Productivity Network (CIRIA) and the industry-led CRINE Network and ACTIVE Engineering Construction Initiative. So far, across the industry, many important lessons have thus been learned and insights gained from practical experience in developing and applying such innovative tools and techniques.

Culture Change and Managing Knowledge

Although these innovations are of course very diverse, they share in common the underlying presumption that a change in culture is needed that brings construction practice more in line with best practice and current thinking in other industrial sectors, most notably manufacturing. It is believed that construction firms can thus improve their competitive performance by reconfiguring their business processes and applying experience and innovative techniques from other industrial sectors to deliver projects more efficiently and effectively. However, there remain significant gaps in understanding the issues involved in implementation and in effecting any such cultural change across different contexts. Part of the reason for this is the paucity of research examining the social, political and psychological dimensions of attempting to implement new technological and managerial mechanisms, tools and techniques. Indeed, recent overviews of research in construction have highlighted the pressing need for further research into cultural aspects of change in the construction setting and the importance of supporting human resource management strategies and practices (EPSRC, 1999).

Research on partnering, for example, has shown that it has significant potential benefits, but that these depend upon sustaining a number of behavioural and attitudinal changes to support collaboration in both the short and long term (Bennett and Jayes, 1995, 1998; Holti and Standing, 1996; Barlow et al, 1997; Bresnen and Marshall, 1998, 2000a, 2000b). Moreover, greater steps towards collaboration in the supply chain depend crucially upon the persistence of appropriate socio-economic conditions that make continuity in the relationships between clients, contractors and suppliers feasible (Construction Productivity Network, 1997). Similarly, it has long been recognised that the potential benefits of IT are only fully realised if technological applications are in harmony with social systems and user needs (Swan and Clark, 1992; Swan, 1995; Scarbrough, 1996). For example, the success of IT applications to enhance integration via information sharing and 'open book' dealings may hinge crucially upon there being some degree of trust in the relationship. Performance improvement initiatives, such as benchmarking, continuous improvement and value management may also have significant benefits in helping reduce project costs and increase value. However, their impact in the longer term is predicated upon there being mechanisms available for capturing, extrapolating and, more importantly, applying the knowledge and learning generated.

Although research has stressed the importance of changing attitudes, beliefs and values to support the introduction of new integrative and performance-enhancing tools and techniques, emphasising the importance of change is not the same thing as explaining how it is achieved. Commonly, prescriptions for implementing innovative approaches fail to trace through their behavioural consequences, with the result that recommendations for 'best practice' can fail to achieve the required degree of social realism that makes them pertinent to practising managers and appropriate to their circumstances. Part of the task of research must therefore be to understand the factors influencing processes of diffusion, take-up and implementation of new ideas, not only throughout individual organisations, but also through identifiable 'communities of practice' with shared interests in the same practical recommendations (Brown and Duguid, 1996).

A FRAMEWORK FOR UNDERSTANDING KNOWLEDGE CAPTURE AND LEARNING IN THE CONSTRUCTION FIRM

Attempting to appreciate fully the problems involved in implementing all of the above initiatives is of course very ambitious. However, an important start can be made by identifying and examining the factors that influence the types of knowledge and expertise required and the impact that these have upon the practical implementation of certain types of innovative management practice, such as partnering, benchmarking and value engineering. In turn, this can help produce a clearer modelling of the processes involved in implementing change in the construction firm.

The problem here is that the widespread diffusion of innovations requires that they be context-free in order to maximise their portability and transferability (across projects, organisations and sectors). However, implementation of these ideas is context-*specific*: companies need to make them work according to their particular needs (cf. Swan and Clark, 1992; CRISP 1999). In the process, a tension is created between the more abstract formalised tools and techniques available and the internal management processes used in attempting to apply this knowledge to practice (Hislop et al, 1997).

Moreover, a key problem facing any attempt at achieving sustained cultural change in the construction industry is the difficulty in attempting to develop, apply, capture and transfer knowledge and learning in what is essentially a project-based environment. There are a number of reasons why this is a particular problem, which can be grouped according to three main sets of factors.

- **Project-related factors.** The one-off, customised and complex nature of many projects makes it difficult to apply the knowledge gained on one project to projects being undertaken elsewhere, often in very different task circumstances and in response to the needs of particular clients. Projects are also transient and life-cycle based and this can make it extremely difficult to establish the repetition and routinisation necessary to apply standardised techniques and codified knowledge (Edelman et al, 2000).

- **Contract-related factors.** Because of the significance of contracting, lack of continuity in relationships between clients, contractors and others in the supply chain is the norm within the industry and this lessens opportunities for learning. Obviously, the commercial relationship itself may also inhibit the development and diffusion of knowledge and expertise, to the extent that it reflects a high level of competition or a low level of trust (Bresnen and Marshall, 2000a, 2000b). Furthermore, because of the multi-organisational nature of project organisations (Cherns and Bryant, 1984), project management processes occur at the interstices between organisations. Any knowledge and learning generated is therefore likely to serve quite divergent organisational purposes and perhaps only partially 'map onto' management processes in individual organisations.

- **Organisational cultural factors.** Any knowledge and learning generated is likely to be influenced by different professional and functional perspectives represented by the organisations involved. One implication is that knowledge and information may 'make sense' to organisations in very different ways because of the different systems of meaning being applied (cf. Trompenaars, 1994; Weick, 1995). Another is that there may be problems encountered in the internal diffusion of knowledge due to the existence of different frames of reference. Functional specialisation is of course likely to be an important source of such differences and may even reflect the existence of different 'subcultures' within the organisation (e.g. Meyerson and Martin, 1987). Problems are also likely to be exacerbated by vertical differentiation and, especially, the spatial and psychological distance created by the separation of site and office-based activities.

These factors taken together suggest a number of important features of, and constraints upon, the capture, diffusion and retention of knowledge and learning associated with new ways of working within the firm. First, that the diffusion of knowledge and learning about new ways of working has important social dimensions, as opposed to being purely technical problems requiring technical solutions (Scarbrough, 1996). For example, is it sufficient to develop IT-based tools and techniques for capturing and sharing knowledge and learning? Or does work need also to be organised (and people incentivised) so that such techniques are used effectively (Scarbrough et al, 1999)? Processes of knowledge capture, transfer and diffusion obviously need also to be able to attempt to capture more 'tacit' types of knowledge associated with new ways of working (Nonaka, 1994).

Second, that an important element in capturing and retaining such knowledge involves codifying and embedding it within a shared system of meaning that cuts across organisational barriers and boundaries and reaches those it is meant to reach within the complex web of relationships involved in any project. This process is made extremely difficult by the many cross-functional, cross-professional *and* cross-organisational systems of meaning, language, values and norms that new developments are expected to embrace. 'Partnering', for example, can mean many different things to different people (Barlow et al, 1997), as too can concepts like 'value', 'risk', 'performance' and 'trust' (Kramer and Tyler, 1996). Indeed, the very meanings of such terms may need to be negotiated.

Third, that such knowledge and learning needs to be able to transgress spatial, temporal and cultural discontinuities associated with internal differentiation and lack of consistency of relationships at individual, team and organisational levels, if longer term learning is to occur. This raises questions about how new initiatives effectively 'cascade' down the organisational hierarchy to affect relationships at operational levels; how they diffuse throughout organisations from one project team to another; and how they survive the departure of key individuals who take their 'tacit' knowledge and skills with them.

Knowledge Management, HRM and Change

There are two further common threads that run through the above discussion concerning the relationship between culture change and managing knowledge. These concern the existence or otherwise of supportive human resource management practices (cf. Legge, 1995; Scarbrough et al, 1999), as well as appropriate strategies or practices of managing change (cf. Collins, 1998).

With regard to human resource management (HRM) practices, many of the initiatives mentioned earlier place a strong emphasis upon the tacit skills and knowledge of individuals and groups (for example, the inter-personal skills and team-working attitudes required by partnering). Such knowledge is notoriously difficult to capture and codify, because it depends upon the intuitive know-how of individuals (Blackler, 1995; Nonaka, 1994; Nonaka and Takeuchi, 1995). However, it may be especially difficult to capture and diffuse when teams are constantly disbanded and re-assembled, as is normally the case in construction. Again, lack of continuity – this time at the individual level – becomes a factor inhibiting knowledge diffusion and learning (Bresnen and Marshall, 2000c).

It is therefore likely that staffing practices and other HRM dimensions (especially team selection and training and development in appropriate skills) have an important potential impact upon the capture of knowledge and expertise and cross-project learning, but that this potential is untapped. For example, socialisation processes resulting from recruitment, induction and training have an important part to play in creating and reinforcing 'encultured' knowledge (Blackler, 1995) and in sharing 'tacit' knowledge (Nonaka and Takeuchi, 1995). However, a more pragmatic approach to staff selection and deployment based on availability is unlikely to produce such effects. Similarly, do reward and staff development practices encourage the retention and development of appropriate skills and abilities? HRM strategies as a whole are underdeveloped in construction (Druker et al, 1996) and the focus of a good deal of debate elsewhere (e.g. Legge, 1995). However, this by no means precludes being able to assess the effects of different parts of the 'package' of HRM measures upon knowledge transfer and organisational learning.

With regard to managing change itself, the manner in which change is introduced and the ways in which attempts are made to transfer and diffuse knowledge and learning may have a crucial effect upon cross-project learning. Research into partnering, for example, stresses the importance of continued senior management support for the concept, a supportive culture and even partnering 'champions' to mobilise support where necessary and increase the chances of enthusiastic acceptance (Bennett and Jayes, 1995, 1998; Barlow et al, 1997). More general management research makes it clear that any organisational change disrupts existing routines and patterns of authority, status and power, often with negative effects (e.g. Pettigrew and Whipp, 1991). Consequently, understanding the effects of internal contextual factors and the consequences of different implementation processes (e.g. whether participative or not) is crucial. It is certainly well established that different approaches to change can have a considerable impact upon whether new initiatives are enthusiastically accepted or whether they encounter indifference or resistance (Kotter and Schlesinger, 1979).

RESEARCH AIMS AND METHODOLOGY

The research that is being conducted to explore these issues was designed to identify and examine the factors influencing culture change and knowledge management practices within a range of different types of construction firm and across a range of related initiatives (e.g. partnering, benchmarking and value management). Particular emphasis is being placed upon charting the impact of human resource management and change management practices influencing the development and implementation of new management practices and new ways of working.

The broad intention of the research is to yield insights that contribute towards a clearer modelling of the processes involved in implementing change in the construction firm. Its specific objectives are:

- To identify and examine the factors encouraging and inhibiting knowledge management and culture change strategies needed to implement new initiatives within construction firms

- To identify the human resource management and change management practices supporting such initiatives and to assess their impact upon the diffusion of knowledge and learning throughout the organisation

- To generate analytical tools and practical recommendations that firms can use to improve their ability to implement and manage new initiatives

The Unit of Analysis and Cross-Sector Comparisons

The research will pay particular attention to examining crucial within-firm cultural similarities and differences and their effects, especially those pertaining to the interface between site-based and office-based staff. Much existing research on innovative management practices in construction takes the *project* as the unit of analysis. This enables project management processes and concerns to be directly addressed. However, the downside to this is the difficulty in extrapolating any lessons learned to other types of project. This research, in contrast, takes the construction *firm* as the unit of analysis, focusing upon internal management practices and policies and how these may be developed to address a wide and diverse range of operating requirements linked to quite different project objectives. This reflects the still overwhelming need for the development of internal capabilities that enable individual firms to respond effectively to commercial opportunities and threats – including those presented via collaborative working within the supply chain (e.g. Holti and Standing, 1996).

A further important feature of the research is the emphasis on comparing and contrasting approaches to change found in different types and sizes of construction firm. Many recent initiatives in construction draw heavily upon the experience of large-scale firms, often in particular sectors (partnering and the oil and gas sector is one obvious example). As a result, the effects of organisational size and cross-sector differences tend either to be ignored or assumed to be neutral. However, there is good reason to believe that such differences matter. With regard to size, on the one hand, for example, it might be that larger contractors are able to employ specialists to develop more systematic IT systems and HRM practices that support knowledge diffusion and learning associated with new ways of working. On the other hand, smaller firms may suffer less from problems caused by internal complexity and thus be more responsive and adaptable to external pressures and changing conditions. With regard to type of work, companies specialising in a narrow range of work, for example, may find it less of a problem dealing with the effects of internal differentiation than do firms whose portfolio of work is more diverse and heterogeneous.

Research Methods

Current knowledge concerning the above concepts and ideas and how they apply to the construction setting is patchy to say the least and arguably nowhere near the point at which it is possible to think in terms of producing tools for quantifying the effects of 'cultural' variables (Bresnen and Marshall, 2000a). Moreover, the framework outlined above emphasises the elusive, subjective nature of many of the key concepts involved, their complex inter-relationships and the dynamics of change associated with the implementation of new management techniques.

These features of the research problem and the importance too of grounding any practical recommendations in an appreciation of context mean that the research inevitably needs to take an in-depth, qualitative case study approach (Bryman, 1989, Yin, 1989). Case studies allow one to explore the complex relationships between culture change, knowledge management and HRM practices in a holistic way. They also help ensure that comparisons and contrasts can be drawn across different projects and that views and opinions can be elicited from different parts and levels of the organisation.

The main form of data collection will consist of semi-structured interviews with samples of staff selected systematically from across a range of relevant organisational locations and levels. Interviews will be conducted with senior operational and personnel staff, as well as a range of site and office-based staff, including representatives from different functional groups (e.g. engineering, planning, surveying). These interviews will be supported by the collection of documentary evidence and, where appropriate, the use of direct observation.

CONCLUSION

At the time of writing, the research outlined above is in its very early stages and, consequently, results are not available. The paper has therefore attempted to outline the conceptual framework and methodology to be employed for the research and to highlight some of the key themes and issues that emerge from considering the nature of implementation processes in the construction setting. To summarise, it has been suggested that existing research is limited in the light it throws on the ways in which project, contractual and organisational cultural factors enable or inhibit attempts to implement change. It has also emphasised the importance of supporting human resource management practices and of understanding the effects that change management strategies themselves have on the implementation of new initiatives in as complex an organisational setting as that found in construction.

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Integrating Knowledge Management and Innovation in Civil Engineering

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INTRODUCTION

This contribution discusses on a conceptual and empirical level how knowledge management and innovation can be integrated in the effort to maintain and develop competitiveness of civil engineering firms. Civil engineering is facing several challenges. Products are becoming increasingly complex and multi-facetted and at the same time manufacturers of components and contractors increasingly take over parts of the design tasks. Elements of the future competitive strategy could be to increase horizontal collaboration in the supply chain, including partnering, the use of IT (Lakka and Kähkönen, 2001) and management innovation. This paper focuses on the second strategy. Knowledge Management (KM) encompasses the use of information systems and soft management tools such as organisation, training and office design (Sverlinger, 2001, Koch 2001). Innovation management is viewed as an issue of establishing internal and external networks, leading innovation processes characterised by unforeseen events and as political action of establishing and maintaining coalitions.

The proposed link between innovation management and knowledge management emphasises the role of leadership exercised on the backbone of an existing and established infrastructure. It is argued that KM can be a central lever for some construction firms in realising innovation, if the focus moves from the infrastructure to leadership. The case illustrates this point. The civil engineering company has well established management routines handling existing knowledge, but lacks explicit innovation management initiatives. Leadership is generally established by top level management but needs to be better coordinated and orchestrated with other managers and employees and requires to be developed focussing on innovation.

The article is structured as follow. After presenting the method, the paper states the prime challenges for contemporary civil engineering companies. Conceptualisations of knowledge management as well as innovation management are then presented. Leadership is subsequently discussed as a possible integration field. This is followed by a presentation of the case enterprise analysed through first a knowledge management perspective, second an innovation management perspective before we conclude.

METHOD

The main conceptual approach in the paper is interpretative sociology. The theoretical elements stem from management; sociological and economic approached to innovation and anthropological contributions to the discussion on knowledge and on management of knowledge.

The paper's empirical part draws on case material from a single Danish engineering company covered by two studies. The first, is a short qualitative study, the second is an in depth ethic ethnographic study (Denzin and Lincoln 2000, Martin 2001). The company has been visited several times by the author but it is investigations carried out by Rolf Simonsen which is the backbone of the material used here (Simonsen, forthcoming). Simonsen was employed for five months in a cooperation project between the Danish Technical University (DTU) and the company with the aim of studying and improving KM in the company. Simonsen participated in three projects, doing participant observation and carried out interviews and dialogues with members of the organisations. This was supplemented with written material from the company.

The company, which is a medium size firm, is treated anonymously here. This implies that certain engineering specificity and dates are kept unclear on purpose.

THE CHALLENGES OF CIVIL ENGINEERING COMPANIES

Civil Engineering companies face challenges from several angles:

- Component's manufacturers, contractors and other players in the construction industry to an increasing degree develop capabilities to manage parts of the design process, which previously were the domain of civil engineering companies.

- There are more and more materials and components available, wholesalers and manufacturers gain advantages and strive at innovating their products. The competence building on these materials and components by the other actors in construction is delayed or lacking.

- Products of civil engineering become more complex, and become integrated systems solutions and services. Many firms need both to develop new capabilities and to establish alliances with partners to deliver (Gann, 2000).

- New ways of managing, new IT-solutions create a change push on the civil engineering companies (as with many others)(Egbu and Sturges 2001).

- Globalisation and capital concentration implies options and challenges for merging, strategic alliances, new competition

The focus in the present paper is on the challenges related to new ways of managing internally, which is however carried out in an context tainted by the other challenges.

KNOWLEDGE MANAGEMENT

Knowledge Management is a still contested and emergent term. At the same time multiple perceptions on knowledge, knowledge production and management flourish (Sverlinger 2001, Koch 2001). Here Knowledge Management (KM) is defined as management activities that frame and guide the knowledge production in an organisation. The knowledge production in itself can be understood as a combination of retrieval, arrangement, creation and erasing of knowledge. Some authors believe that a clear distinction can be made between data- information-knowledge or between different types of knowledge like tacit and explicit (like Davenport and Prusak, 1998, Nonaka and Takeuchi, 1995). These distinctions are tempting in their clarity, but less applicable in practice (Robertson et al 2001). The position adopted here thus refrains from such distinctions and lean towards understanding knowledge as contextual and cultural. There is also a lack of consensus on which tools and activities characterise KM. But across the contributors one can point at a set of generic areas with certain common activities. Corporate and strategic management, information systems, organisation, human Resources, office design and culture are common denominators.

Within *corporate and strategic management* one can direct at the formulation of a knowledge management strategy, the communication and clarity of it (Sverlinger 2000). The appointment of a responsible top level manager and or a knowledge officer is another central activity. The effort to bring evaluation tools in place, monitoring knowledge as an asset and calculation knowledge balances have been central (Bukh et al 2001). *Information systems* were initially thought as the central tool of KM (Ruggles 1998) and are still understood as having an important role (Robertson et al 2001). Systems include technologies such as Intranets, groupware, list servers, knowledge repositories, database management, dataware-housing, datamining and knowledge action networks (Blumentritt and Johnston 1999, Ruggles 1998). *Organisation* focuses on establishing network on specific engineering topics and a changed role of middle management. *Human resources* relate to developing competency profiles, designing recruitment and training and to designing reward system (Davenport and Prusak 1998, Swan et al 1999, Sverlinger 2000). *Office design* relates to a shift from traditional open office landscapes and cells; where individuals either work in parallel on tasks that are assigned to them or in singular offices (Duffy 1997). This traditional form was an underpinning of hierarchy, where managers and senior expert employees have their own offices, whereas clerks, junior employees and others work in open spaces. In the new office concepts a direct support for different knowledge activities is sought (Duffy 1997) the office is supposed to support group interaction, intensive individual knowledge work (cells) and networks. The *culture* aspect has been addressed by the literature on knowledge intensive companies (Alvesson 1995) and on communities of practice (Wenger 1998, Brown and Duguid 2000). KM is here about "installing" a knowledge sharing culture, which will often collide with existing organisational cultures, for example constituted by professional groups (Bloor and Dawson 1994).

The knowledge production within construction is closely related to projects realising "one of a kind" production. The knowledge production is however also relying on the ability to re-use and mobilise existing knowledge on the different element of the construct. The end-product site is central in the process and is moved for every project. Moreover a central characteristic is the organisation of the supply chain which exhibits a specific division of labour and institutionalised roles such as the manufacturers of basic parts, the engineering companies, the building companies (including groups of craftsmen) and the builder. Although there are examples of transcending these institutionalised roles, they are roughly maintained in the majority of building projects. Therefore every project needs some kind of cross-organisational organising, thus making the knowledge production process an inter-organisational task. The design phase usually encompasses such collaboration with one set of actors, whereas the realisation phase features the site, where the building is realised, as another coordination space across the mentioned groups.

INNOVATION MANAGEMENT

Management of innovation is increasingly seen as best conducted through establishing and maintaining networks, where these are aligning internal and external elements (Mcloughlin et al 2001). Gann thus points at successful improvements in the nineties in UK construction industry, where he demonstrates that structured approaches to promote innovation involving collaboration between industry, government and research were put in place (Gann, 2001). Winch takes a more ambivalent view on the combination of internal and external alignment and point a number of hindering factors in innovation, such as price structures (Winch, 1998). Winch rightly points out that the majority of innovations in construction need to be developed and appropriated within projects, which are temporary alignments of internal and external resources. The construction sector is thus marked by reactive project based product innovation (as also for example the majority of the machine tool industry is). A central problem is to embed such innovation in the company on a more permanent basis and across projects. It should be added though, that Winch implicitly focuses on product innovation rather than (internal) process innovation.

Innovation processes has an emergent character and involve political action and coalition building (Van de Ven et al, 1999, McLoughlin et al, 2001. Setbacks shifts in criteria as shocks are part and parcel of the process. Van de Ven et al and McLoughlin et al also underline the understanding of innovation as a multi-actors activity, in contrast to quite some writers, who still underline the position of a single champion as central. Winch perceives the principal engineer or architect as having a central role in innovation (Winch 1998). Van de Ven et al discuss the coalition building in term of intersecting leadership roles (see below)

Learning and knowledge are in newer innovation management literature seen as central sources and central features to management tasks (Leonard-Barton 1995). Gann (2000), in his discussion on construction innovation, argues that the needed knowledge in innovation is expanding faster than resources for training and research. He identifies this process in two dimensions: The breadth of knowledge measured by new specialist disciplines and the depth of knowledge measured in the extent of education needed. The argument is that successful innovation needs a mode 2- regime of knowledgeable team players (Gibbons et al, 1994, Gann, 2000:227).

Summarising, innovation management has, following Gann, three main components: Leadership, competent interdisciplinary people and appropriate infrastructure to support implementation.

THE POTENTIAL FOR INTEGRATION?

Given the strong knowledge component of innovation and the induced interest of knowledge within innovation management and given the further interest in among other things human resources, one should think that and integration of innovation management and knowledge management would be straight forward. As described above however knowledge management (KM) has a much broader focus on handling knowledge in an organisation than innovation management and moreover the innovation component of KM is actually weak. Finally KM leans heavily towards management and gives little attention to leadership.

Integration of two types of management should preferably leads to some sort of added value. Moreover it should offer companies using state of the art management a step forward. The argument here is that a potential integration should add something new to existing activities. The argument here is therefore to integrate the two areas from a perspective of leadership. Van de Ven et al –s conceptualisation of innovation leadership understands it as active and collective (Van de Ven et al, 1999: 97, see also Bryman, 1999). It contains four intersecting management roles: sponsor, mentor, institutional leader, critic, and relates to the entrepreneur who carries out the innovation process.

Innovation and Knowledge leadership could focus on what Ven et al label “learning by discovery”. Since KM and innovation management has provided the necessary infrastructure (Gann, 2000:228). The leadership aspect is then to create space and frames, which could be done by the mentor, and to be a critical towards new knowledge (Van de Ven’s role of the critic). In the beginning, knowledge will be articulated as relatively weak fashion as claims, but which might be extremely important for new product’s development.

THE CASE

The engineering company described below, actively work with knowledge management as part of its corporate strategy. The elements of knowledge management are corporate and strategy management, information systems, organisation, training and personnel issues, office design and culture.

The company employs around 500 members of staff. The organisation is matrix-like. The focus horizontally considers customer groups and/or products, whereas the vertical focus concentrates in major areas of competence. The company have major competencies, albeit with different emphasis, within:

- Heating and Sanitary Engineering
- Electrical Engineering
- Building Physics
- Construction Management
- Consultancy

Top level management was renewed roughly ten years ago. Since then a number of new management recipes has been adopted including strategic planning, new office, branding and IT. It should be noted that leadership clearly plays a role in the acts of top level management. It is understood here however a general type of leadership such as communication of strategic goals.

The knowledge management

The KM strategy for the company is directly linked to *corporate competitive strategy* and is organised with close links to top level management, as one member of the board of directors is responsible for knowledge management as such. The company has ongoing KM activities and takes further initiatives to realise KM. Knowledge and innovation play a role as part of the external branding of the company as well. The company has implemented means to evaluate its strategy and its knowledge component. The company employs several *IT-systems* including accounting/ERP, CAD and project management tools. All these systems play a role in managing knowledge in storing and providing different forms of information. Several of the systems were implemented before the knowledge management strategy was made explicit, but a further and more integrated use has been a central element of KM. Especially the intranet and an enterprise portal has been positioned as central in the first effort of KM. Moreover integration between systems has become a central preoccupation. In both companies however employees receive the effort with ambivalence and the KM-functions of various kinds are not used overwhelmingly. The Intranet is used to store and support information on various knowledge areas. The capture of best practices and the facilitation of professional networks are central elements. Also more "mature" explicit information such as standards, guidelines, templates for formulas and other documents are part of the intranet-facilities, not to mention e-mail communication, bulletin boards and corporate information. The aim is that codified knowledge is to be supported by Intranet. The *organisation is characterised by an emphasis on projects* as the main value adder. The emphasis is on small organic departments and fewer hierarchical levels. Three types of managers intersect and each contributes with management of knowledge activities: department and project managers as well as managers of professional networks. KM means focusing on and enhancing existing professional disciplines. These professional networks acknowledge proposals for best practices, which are then registered in the companies Intranet. There is a *strong element of Human Resource Management* in the KM. Recruiting and training are important ways of developing knowledge resources. Moreover there is a large emphasis on making the staying in the company very attractive in order to keep the knowledge acquisitions in the company by trying to develop loyalty among the employees. The management position is however that employement turn over could be improved. The company has experienced a fall in the (previously long) length of employment, after expanding considerably over the last years. Training is used as part of KM but is not uncontested, since some managers and employees feel they mostly learn by participating in direct project work. The company has rearranged parts of the *office space* as part of an effort to physically support sharing of knowledge. The shared open spaces are organised according to the departmental structure in order to support exchange of knowledge within the same specialism. The projects typically cuts across departmental structures and thus still have to meet formally and the member have to interact in other ways. The co-local fashion of interaction is therefore less prevalent and E-mails and phone are largely used. There is an attempt to downplay hierarchy by letting the department manager work in the open space among the other employees. However corporate management has been strengthened, at the same time. *Different department cultures* exist, although this was not systematically investigated. It is likely that a managerially installed "knowledge sharing" culture will collide with project-dynamics as well as professional cultures, which is enforced by the KM-IT and organisation component (support for professional networks).

The management of innovation

The company was for many years, as many other civil engineering companies characterised by the lack of explicit management of innovation. The company did not have and still does not have a R&D-department and innovation is handled as a project. Seen from a corporate management perspective there is as a result a lack of control over the development and prioritisation within existing and potential innovation portfolios.

However, new product and methods are adopted within the on going projects. And in a number of competency areas the company has followed innovative development paths. These specialists' areas include special equipment for manufacturing industries, facilities for office buildings and others. The development of new products (product innovation) occurs in these areas within the frame of interaction with customers and it creates a positive cumulating of knowledge and competency related to a engineering specialism. There is also a clear path dependency for these innovations, certain highly focused and specialised skills generate relatively high turn over. The focus is however not stronger than the portfolio of projects and of competencies are relatively broad-spectre.

A major strategy-work commenced several years ago and still ongoing encompass a series of what can be labelled internal process innovation, but no explicit product innovations. On the other hand prioritised areas of compctencies and knowledge management activities are part of the effort. The company has carried out and finalised a series of process innovation projects. The Knowledge management group is an example. Top level management described the project and a project group was assigned resources to develop KM-tools. The group carried out elaborate discussion on existing practices and found quite a few aspects they thought could be improved. The group described a number of practical process suggestions, which could be used internally. One example is an ex-ante quality review instead of an ex-post one. The idea departed from experiences with the quality procedures. When a project is finalised, it is exposed to a quality review by experienced engineers. Often this revealed a lack of mobilisation of the company's full knowledge in the area. The idea was then to introduce such experiential knowledge into the project process, immediately after a quote had become a project. The knowledge management group delivered an internal report with its suggestions. It was then decided to test the "ex ante quality review"-proposal in a project. A project was selected and the ex-ante review scheduled and carried out. The project was halted however shortly after, because the customer went into a financial crisis. More attempts to implement will be hopefully be made in the coming period.

The internal knowledge management project is an example of process innovation management. Within the process the group develop quite strong understandings of the KM-innovation problems. When trying to implement and embed the proposals however, they and top management face traditional barriers of engineering companies, especially the "single project"- logic. Lately the company has decided to form an innovation team. The innovation team has five members, all top-level managers each with a area of responsibility within innovation. Those are both internal and external and include international affairs, new cooperation forms, business processes and IT and two areas of business development in relation to customers. It is still too early to evaluate this initiative, but it is clearly the closest the company has been to explicit innovation management.

DISCUSSION AND CONCLUSION

The aim of this paper has been to explore the possible integration of innovation management and knowledge management in a civil engineer company. Initially the two forms of management were conceptually identified and it was argued that leadership might be a possible common area. The case focused on the company's knowledge and innovation management. It clearly reflected the general tendency to view knowledge management as management in the sense of establishing and maintaining routines, rather than involving leadership. The company thus employs process innovation to reach a proper status for the management routines. Most of these routines are however best at tackling existing knowledge and information, whereas the creation of new, innovation, needs other forms of management. They are important infrastructure but cannot in themselves be innovative.

The innovation management discourse focuses on leadership, resources and infrastructure as central for innovation. In the case company, the innovation team could be an important lever for such leadership. But equally important are the coordination between the three types of managers: department managers, project mnagers and managers of professional networks. These manager groups should preferably cover the intersecting leadership roles. This leadership could be an extension of the Van de Ven's framework in the sense that "content"-leadership is included in using the managers of the professional networks in an orchestrated interplay with the others. As noted, leadership is generally established by top level management but needs to be better coordinated and orchestrated with other managers and employees. Its development needs to be focussed on innovation.

The internal knowledge management project in the case is an example of process innovation management. When trying to implement and embed the proposals however, they and top management face traditional barriers of engineering companies especially the "single project"- logic. There is clearly a danger that innovation effort in civil engineering continues to be framed by this logic, maybe knowledge accounting as part of knowledge management can develop a new form of accountability, which enlarges the single project frame.

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Framework and Tools for Project Management by

Using a Flow Model of Activities

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ABSTRACT

Building Projects in Japan, are undertaken in accordance with Japan's particular contract customs. For example, when the general contractor has assisted the architect in drawing up the documents, he will most often not receive remuneration for his assistance. Also, the architect is often selected by ways of exclusive relationship with the client. In this case, the architect and the owner develop a mutual understanding from a very early stage, and much of the conceptual design is drawn up without charge. "Building Contracts" do of course exist in Japan, but this form of business custom often takes precedence. Often, a contract is formed at a later date only after the task has been completed to a certain degree.

Although there are a number of problems in this kind of Japanese style project management, it has been long accepted in Japan as the natural matter of course. Recently however, with the downturn in Japan's economy, the number of people beginning to reconsider this style has increased. It is also becoming difficult to continue this Japanese form of project management because of the increased number of buildings in Japan being designed by foreign architects.

In the subcommittee on project management in the Architectural Institute of Japan (AIJ), virtual building projects are created, and become the main part of a new experiment. This is called Virtual Project Management (VPM). The VPM is a form of role-playing test involving all those involved in a project, the owner, the architect, the engineers, and the general contractor, and simulates and reveals what problems may occur under the traditional Japanese style of project management. One of the most difficult problems seen in the simulation was deciding how to what system of procurement to adopt in a project. This is because

after deciding not to use the traditional Japanese building methods, no one was able to effectively evaluate any possible new methods to introduce in its place.

This paper is therefore a proposal on how to proceed smoothly in selecting a method of procurement by using information technology. Deciding upon a system of procurement is just one of the activities involved in a building project. In this paper, we have broken down these activities, chosen to focus on procurement, and would like to introduce a related piece of software. Using the Analytic Hierarchy Process (AHP), this software quantifies both the owner's demands and the procurement systems, and links the two. This idea was first proposed in 1993 by Ichikawa (1994), but in this paper it has been improved by the use of the Visual Basic language.

SELECTING A PROCUREMENT SYSTEM

Until now, many methods have been proposed to evaluate quantifying procurement systems. For example, Skitmore and Marsden (1988) put together 7 types of procurement systems, including Negotiated Traditional, and Turnkey Contracting, which evaluate systems by quantifying 7 utility factors such as speed and certainty etc. Cheung *et al.* (2001) built on these ideas, researched studies done in the past and more widely investigated the selection process of these utility factors. In that paper they compared the mutual relationship of utility factors using the AHP and was logically speaking of the same school of thought as Ichikawa (1994) and the authors of this paper.

How quickly the owner can decide on procurement system is the most important problem. For example, through a survey done in Saudi Arabia, Alhazmi (2000) and colleagues showed that public owners select all of the design and build. However, notwithstanding the fact that we must have a large sample size to gain an accurate understanding of the general trend, even if conditions are all the same, the next job will not necessarily produce the same results as the last. It is important to have a system in place to support the selection of a procurement system under a number of different conditions.

PROCUREMENT SELECTION IN THE VPM

The VPM was but into practice under the following conditions. The International Institute of Architects (IIA; a fictitious organization) was celebrating 50 years since its inception, and it was decided by the administrative board to renew the facilities of the main office in Tokyo, and the construction committee instructed was instructed to make a start. Two of the responsibilities of the construction committee were presenting recommendations to the investors, and to submit proposals regarding the future project manager. Through this, a procurement system with the objective of the construction committee acquiring an acute understanding of the process involved in the project, and one where they could independently participate in management was sought after.

At present, the IIA owns a site and a building. The gross floor area of the building is 3,000m^2. The completion date for the project has not been set, however the expense of having to move to a temporary office for the duration of construction must be considered. As the budget set by the administrative board is a provisional one, the construction committee plans to swiftly submit a requirement proposal to the administrative board.

The biggest problem in the VPM was how to allocate responsibility when attempting to settle on the projects conceptual design. The owner in the VPM was the construction committee and the administrative board. The first debate was whether it would be more advisable to entrust the conceptual design to the project manager (PMr). The construction committee argued that IIA had the extra commitments such as the responsibilities of keeping its members informed, examination into whether the design and build was desirable, and whether or not it was deemed profitable, all of which exceeded the capability of the construction committee.

The tasks which seemed inappropriate were as follows: investigation and enquiries into business aspects, investigation into numerous conditions of law, correspondence with government and municipal offices, drawing up basic plans, creating project management plans, investigation into the ordering system for construction, selection of the architect, a timescale of operations, budget planning, and planning to attract tenants.

Given these weaknesses, which procurement system would be the most appropriate for the owner to select? What kind of system would give the owner maximum satisfaction? These are all problems that the owner needs to solve.

PROCUREMENT SYSTEM SELECTION SUPPORT SYSTEM

In the "PM Selection Support System" proposed in this paper, the owner decides upon the alternative procurement systems using the AHP, and then quantifies them their respective characteristics. The owner then selects the appropriate procurement system by taking into account the data output for each.

Selecting Alternatives

In this paper, we have selected the alternatives in the procurement system down to the following generalized 6 contract systems: separate, traditional, design and build, pure construction management, construction management with guaranteed maximum price, and construction management at risk. These are not evaluated directly, but instead indirectly as “factors to form a pattern”.

The Evaluation of Project Characteristics by the Owner

The general format is that the owner, by way of a questionnaire survey will compare the characteristics of each project, and quantifying them. In this paper, from the results from Ichikawa’s survey, the owner of the VPM cannot only select the most appropriate owner for the job, but we can also predict comparative numerical results representing how this new owner might think regarding project. From these figures, we can gain [0, 1] numerical values from the AHP.

As shown in the left-hand side of the stratum-structure in Figure 1, on the lowest level, through substituting the numerical values for the owner’s opinion, his opinions can be quantified. This system has been set that the total of the internal values of the divided groups will be 1.0. This is the origin of the principles of the AHP.

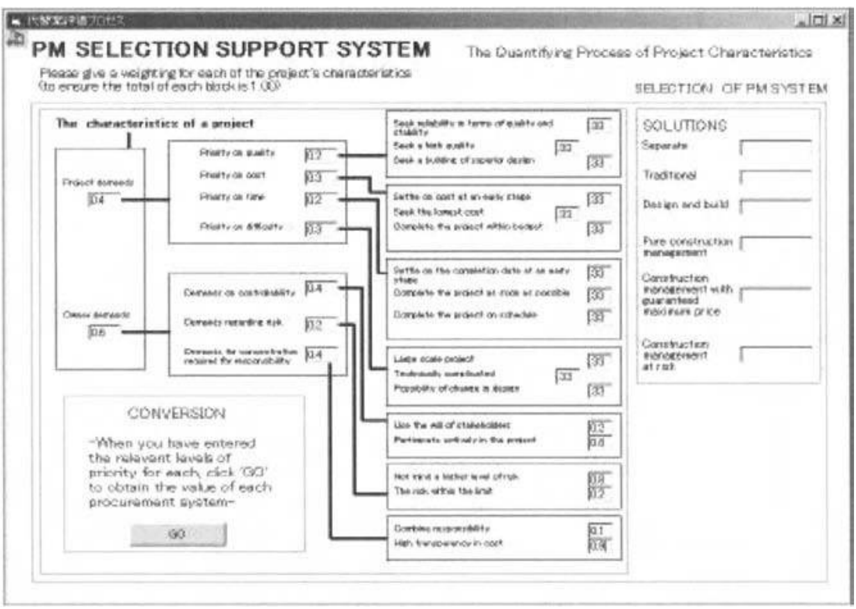

Figure 1 Input screen of PM Selection Support System

Quantifying the Characteristics of a Project

One of the substituted values from each level in the last section is chosen and are multiplied together. This gives a quantified value of the projects characteristics. For example, the projects characteristics of "Seek reliability in terms of quality and stability" as shown in Figure 1 would be as follows:

"Project demands (0.4)" X "Priority on quality (0.2)" X "Seeking reliability in terms of quality and stability (0.33)" =0.0264.

Conversion

Weight is placed on the characteristics of each project. The weight is the influence of this characteristic on the procurement systems functionality and is evaluated by an experienced professional. In this paper, we have used the data gained from Ichikawa's survey. The weight is derived from the functionality of each system. Thus the value each procurement system is gained.

Selection of a Procurement System

Next, we attempt to attain the value of another weighting. That is weighing the influence of the functionality of one procurement system against its alternatives. This can then be used as the ultimate evaluation of the procurement system. Again, this paper uses the influence scores gained in Ichikawa's survey.

APPLICATION TO THE VPM

As noted above, because this system was developed with Visual Basic, we must verify its effectiveness. Ichikawa has proposed a logical solution method using the AHP in an above section, but a definite application for users had not yet been developed. In this section of the paper, we will explore the developed application.

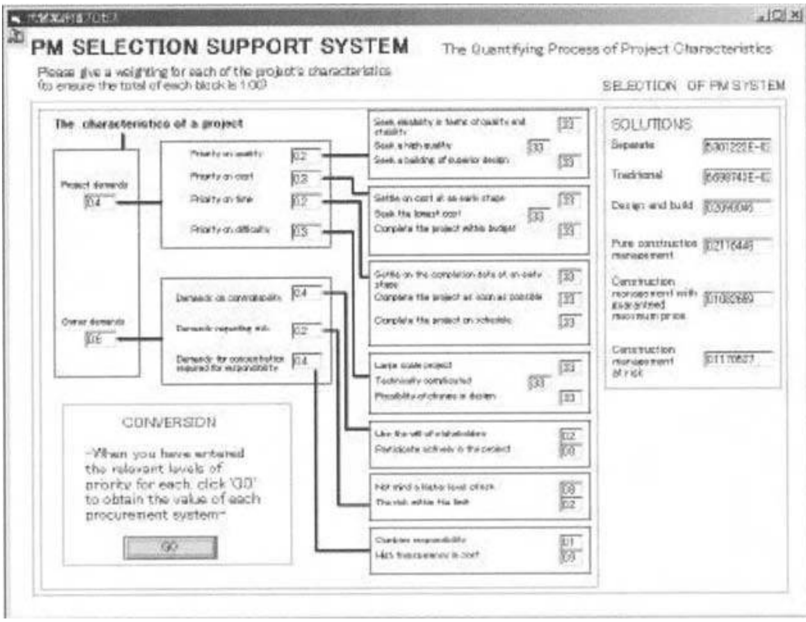

Figure 2 Output screen of PM Selection Support System

In "case 1", we took just the concerns of the owner regarding risk. The owner of the VPM had the same characteristics as noted above, and asked for the general construction costs to be logically and clearly presented. This has in fact been seen amongst many Japanese owners recently, and seems to be an increasing trend. The VPM owner is also aware of appropriately spreading project risk. The outputs for this actual example are shown in Figure 2.

The resulting outputted data is shown on the right-hand side of Figure 2. The "Pure Construction Management" of the VPM owner was a score of 0.199, and was judged as the most suitable. The next best score was "Design and build" with 0.152, and the worst characteristic evaluated was "Traditional".

DISSCUSION

Using the "Selection Support System" it is possible to, in a very short time, select an effective alternative procurement system. While using this system, the owner can change his priority order little by little, and can investigate which procurement system to employ. Through using this simulation, "Selection Support System" can prove to be very effective.

Through the owner of the VPM choosing the "Pure Construction Management" as his procurement system, he have his wish of fulfilled of having all costs displayed. However, the owner, who through the VPM decided that the design and build was not appropriate, and chose the second option of "Design and build" by using this "Selection Support System", is somewhat of an ironic result. Although methods were thoroughly investigated to ensure the owner of the VPM is successful in his project, a problem occurred when it was found that the most applicable procurement system for that project was not yet available in Japan.

CONCLUSIONS

In this paper, we proposed the idea of "Selection Support System" while referring to a number of actual examples using the VPM. This system quantifies the owner's intentions using the AHP, and promptly displays the most appropriate and effective procurement system alternatives to the owner. This system made it simple to discuss management in the VPM smoothly. There are also many other tasks in the VPM, and the methods for their logical implementation must be investigated in the future.

ACKNOWLEDGEMENTS

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Applying Principles of Service Management: Is the Construction Sector Different?

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ABSTRACT

Construction contractors and providers of construction-related services receive impulses from other business sectors. While inspiration has come to construction from the manufacturing industry for most of the twentieth century, management models developed in other parts of the service sector have only more recently won acceptance. Industry specific technical and administrative constraints can be expected to affect the ability to implement and benefit from practices associated with mainstream service management.

In order to identify patterns of adoption of service management practices, Swedish companies, both construction-related and non-construction, have been surveyed here. Interview responses show that construction companies are aware of modern service management practices and that a number of these practices have been adopted. Just which practices have been adopted can largely be explained by reference to sector specific constraints, in particular the durability and immobility of built facilities. From this analysis, it is possible to question the simple time-cost-quality goals for traditional improvement of the construction process. This should affect how we assess the potential for innovations in the management of construction processes.

CONSTRUCTION AS A SERVICE

For many years, firms in the construction sector have looked to leading manufacturers as a paradigm for the industrialization of construction (Bröchner, 1997). The emphasis has shifted. Sometimes, manufacturers have been seen as more efficient because of their ability to draw benefit from mass production based on standardized components; more recently, their methods of encouraging and implementing innovative technologies have been in focus. Riley and Brown (2001) have recently warned against transfer of manufacturing practices to construction, arguing that the distinction between construction as a project culture and manufacturing as a company culture is relevant and an obstacle to transfer. From an innovation viewpoint, the development of business processes and not just project processes is now seen as crucial for the construction sector (Gann and Salter, 2000).

Lately, globally competitive manufacturers have shifted towards emphasizing combinations of tangible and intangible products, drawing lessons from advances in the development of mass services for individual consumers. As it is easy to argue that most firms in the construction sector actually deliver services (Holm, 2000), it is worth asking how construction functions in a service management perspective, and there is a growing number of investigations into service aspects of construction (Al-Momani, 2000; Hoxley, 2000; Love et al., 2000; Torbica and Stroh, 2001). To an increasing extent, manufacturing resembles construction when production is projectified, customers become involved more closely in the design and manufacture of unique products with no intermediate prototypes, and outsourcing raises the reliance on subcontractors. Thus it seems that most types of production are moving towards a single mainstream set of practices, almost regardless of traditional sector differences.

Firms in the construction sector are either totally to be classified as service producers, notably those like architects and engineers who produce pure information services, or property owners who lease space to firms and households, also a typical service offer; construction contractors can be viewed as being dominated by service features, while firms that produce turnkey homes come close to the position of the traditional automotive manufacturer.

The last two decades have seen a rapid development and codification of service management practices, not least the body of practices known today as CRM, customer relationship management. The present investigation analyses how service management practices have been adopted or rejected by firms in the construction sector. The assumption is that the pattern of adoption can be explained by fundamental technological features and constraints of construction and constructed facilities, and that these elements can be identified.

There are three important service delivery processes related to construction: design, actual construction and facilities management. These are intimately linked; the product quality of the design service process affects both the product and process quality of the construction process on site, and the product and process quality of construction affects the quality of the facilities management process. Obviously, there are several interpretations of 'customer' that arise from there being more than one process. The end customer is identified here as the user of a building, but even that interpretation leaves us with a degree of ambiguity; there are both employees and visitors in most offices.

SERVICE MANAGEMENT PRACTICES

Current practices associated with good service management can be divided roughly into customer orientated and employee orientated. However, there is no clear consensus among researchers on how to structure the field of service management. Influenced mostly by Grönroos (2000) and Heskett *et al.* (1997), the following classification of practices has been applied here.

First, there is a set of management practices that are aimed at the market and customers. Here we find market segmentation and the differentiation of approaches to various segments of customers. There are also models for the development of services, with or without customer involvement in design and delivery. A crucial issue is the development of service process qualities, often with a focus on the service encounter. There may also be the development of additional or augmented services on a more or less individual customer basis. Other practices related to these are the offering of service guarantees and the introduction of routines for service recovery when service delivery has failed. A major area concerns models for encouraging and using feedback from customers, directly to the frontline, through periodical meetings, interviews or standard surveys of customer satisfaction. Closely related is the evolution of easily accessible records per customer.

Secondly, with an aim primarily at service firm employees rather than customers, we find practices such as service quality focused recruitment procedures and devising rewards linked to quality feedback from customers. In a geographical dimension, there are policies and methods for homogenizing service delivery at multiple sites. Often more easily identified, there is the flattening of hierarchies to reduce the distance between top management, frontline staff and customers. Furthermore, there is frontline empowerment, intimately linked to the existence of information systems that provide access to prior information on customers.

Finally, there is the development of visions and strategies for the service firm and communicating these to employees, suppliers and customers.

TWO SURVEYS

The diffusion of service management practices among companies that deliver construction-related services is studied here by contrasting a number of such companies with other service companies.

Two surveys with semi-structured interviews were carried out in 2000 and 2001 with a total of 41 managers, working as project managers, marketing managers or sales managers in construction-related and other service firms in Western Sweden. Many but not all of these held regional functions in companies with a greater geographical coverage. In-depth interview questions were related to management practices and were formulated partly with inspiration from the Service Profit Chain Management Audit (Heskett *et al.,* 1997). For each type of practices, pairwise comparisons were performed by the same team of interviewers; at least one of the firms had to belong to the construction sector, while the second firm was chosen from the broader service sector. This does not exclude that in a few cases both firms were from various parts of the construction sector.

Construction and construction-related services were represented through two road contractors, one of which was municipally owned, one housing contractor and one general building contractor. There was also one supplier of prefabricated mobile housing units. Pure information services providers included two engineering consultants, three architectural firms and one property development consultancy. On the property side, there were representatives of both housing and commercial property companies from the private sector, one municipal housing association and one student housing association. There was also one provider of facilities management services.

Non-construction-related companies in the two surveys included three information technology and telecommunications service companies, three hotel chains, one fast-food restaurant chain, one catering group, one travel agency, one office services provider, one express delivery group, one establishment of higher education, and finally one car sales function.

DIFFUSION OF SERVICE PRACTICES

Which practices were found in the companies in the surveys? Interview findings are presented here according to types of service management practice. The intention is also to highlight differences between construction-related companies and other companies. The distinction between customer orientated and employee orientated practices should not be taken too strictly, since practices such as 'frontline empowerment' intend to combine both orientations.

Customer orientated practices

Seven types of practices can be classified as mostly customer orientated. These are represented here roughly according to a process view of customer relations, beginning with the initial identification of potential customers and ending with feedback practices.

Market segmentation

Of the two engineering consultancies in the survey, one aimed at a broad range of project types and had implemented a customer database earlier than the other consultancy, which was more narrowly focused on construction technology and on large customers, loyal over a long period, more than ten years. One architectural firm concentrated its customer satisfaction efforts to customers who were either quite satisfied or dissatisfied; key customers were allowed to select which team they were to work with. A commercial real estate company had recently introduced a customer care programme, based on three customer segments, where also profit and growth per segment could now be analysed. One housing association preserved loyalty among potentially exiting tenants by giving them preferred access to the rest of their stock. In one hotel case, there is a sharp line between business guests during workdays and weekend leisure guests; earlier guests are targeted for marketing, using a detailed database.

Service development

In addition to the widespread use of customer questionnaires for input to the development of new or improved services, one housing developer used behavioural studies. It was reported from both construction and non-construction companies that employee availability had been increased as a consequence of questionnaire surveys. As expected, customers are often involved in construction design. A regional contractor had developed its services because of client demands on quality and environmental issues. However, there were no companies who went as far as calculating their costs against the increase in customer value for new services.

Additional services

No additional services such as new kitchen equipment were offered by a private sector housing provider, in contrast to one software company that often modified its standard version and adjusted prices accordingly. On the other hand, another housing association tried to influence the municipality to raise the standard of school and other services in the area. Residential tenants were given free events and museum tickets to preserve loyalty in another case. One commercial real estate company now offered its office tenants optional electricity supply contracts and waste disposal. One hotel group had unbundled its services and had started charging separately for breakfasts.

Process qualities

One housing provider worked with those tenants who disturbed other tenants, instead of evicting them. One software company had accommodated its products and processes to the fact that many of their customers were highly sensitive to disruption of their own primary production processes. The two engineering consultancies had both obtained ISO certification for their quality systems, although the construction focused engineers tended to give priority to end product quality while those engineers who worked for a broader spectrum of customers gave priority to raising the service value. Also, the mobile buildings supplier thought in terms of product quality being more important than service qualities in winning customer satisfaction. Architects pointed to the creative nature of their work as an explanation for their lack of interest in quantifying service quality. One catering company used 'mystery shoppers' to gauge process qualities.

Service guarantees

Except for clauses in the standard forms of contract used in construction, and the implicit guarantee in a certified quality system, nothing was found that matched one hotel chain that guaranteed satisfaction within a 15-minutes limit.

Service recovery

One engineering company that depended on a small number of loyal customers had no formalized rules for settling of service conflicts with these. Routines for service recovery were found mostly in companies where loss of customers was expected to occur due to service failure. The mobile buildings supplier would respond immediately through the customer's project manager, just as the architects and engineering consultants had project managers as obvious recipients of complaints. Other service providers tended to have specific staff for handling complaints.

Feedback from customers

Almost all companies spent considerable effort on questionnaires to customers, either annually, after the completion of projects, or to tenants when they wished to move. Usually, external survey expertise was bought. Results were used as an input to service development. These feedback practices were widespread but more of an innovation in the construction sector companies.

Employee orientated practices

Five service management practices with an emphasis on employee relations have been selected.

Recruitment

Changes in recruitment practices were noted. One real estate company reported that their previous emphasis on technical skills of new employees had been modified by taking personality traits into consideration. A similar development could be identified by the travel agency that used to recruit sales staff from their pool of travel guides at foreign destination, but now looked more for individuals with process quality skills. This shift was also accompanied by greater reliance on individual recommendations from their present employees.

Quality-based rewards

Regardless of sector, there were very few cases of employee rewards being based on feedback from customers, in questionnaire form or otherwise. Union traditions were also mentioned as an obstacle to bonus payments to frontline workers.

Multisite operations

Companies that operated from offices in more than one region indicated an evolution towards stricter management of their brand and a new emphasis on unitary outward appearance. Nevertheless, local initiatives and local ways of working were encouraged among the construction-related companies, and there was little evidence of regional transfer of customers or of knowledge, although company intranets have started to make their appearance in a few cases.

Flat hierarchies

Several examples of flattened hierarchies were found. The municipally owned road contractor had reorganized according to business categories and abolished certain middle management positions at the same time. The property development consultants had created a flat pool organization in the wake of turbulence after acquiring another company. Companies that had not reorganized mentioned that their information flows between employees had increased greatly, for example by introducing regular meetings where all levels, including workers, were able to participate.

Frontline empowerment

One chain of hotels offered the clearest example of well-defined rules for what frontline staff were allowed to do to satisfy individual customers. The emphasis on frontline empowerment is spreading, however. In one case, residential area managers may now procure small repair work from external contractors. Comparing the travel agency to a commercial property owner, the latter had only recently taken the frontline relations seriously. However, traditional labour relations were mentioned as an obstacle to the empowerment of individual construction workers.

Visions and strategies

The development of a strategic market vision was compared for a road contractor subsidiary of a large national construction group and an IT consultancy. Respondents in both companies emphasized simplicity, credibility and clarity of company vision, for both customers and employees. However, the rapid rate of development in the IT industry leads to a need for frequent updating of the corporate vision, which contrasts with the stability of markets and technologies experienced by a road contractor. For the road contractor, reference projects are important for its credibility, while reference customers are important for the IT consultancy. How positioning was interpreted also differed, profit as a criterion for project choice being mentioned by the road contractor.

CONSTRUCTION SECTOR CONSTRAINTS

Using the survey results, it is possible to systematize factors that constrain the choice and implementation of service management practices in construction and construction-related services. Behind these constraint factors, there seems to be two fundamental characteristics of built facilities: their durability and their immobility. Nam and Tatum (1988) also recognize complexity, costliness and high degree of social responsibility as three other fundamental characteristics, but durability and immobility are the two prominent characteristics in the services perspective. Although there are constraints that depend on both the long-lasting nature of most buildings and their fixed location, a distinction between durability and immobility constraints can be made.

Durability of built facilities

Unlike most other services, the product quality resulting from the construction process is difficult to assess rapidly. Hidden faults, if any, may emerge after years of use. Since the physical product is intended to be durable, the production process is lengthy, which means that both customer and provider can be expected to change their priorities while the process is running. This is often linked to heavy involvement of the customer in service design. Taken together, these features make construction projects resemble large, customer-influenced software projects rather than mass-produced, standardized and rapid services.

An intended long life of the product is at least one of the explanations why new technologies emerge slowly in the construction sector. A low rate of introduction of new construction technologies stabilizes positions and market strategies of companies that are active in the sector. Instead, it is the growth of more powerful information technology that seems to drive changes in market positions for these companies, because it supports better coordination in a sector already characterized by multicontractual project relations.

For markets where physical product quality no longer offers competitive advantages for companies, it is easily understood that softer process qualities gain importance. But competition in construction tends to depend on both product quality and process quality.

In addition, government regulation of construction and construction-related services is extensive. If rent control leads to excess demand in a market, cost-minimizing building owners will concentrate on retaining existing tenants, preferably without any relocation. The regulation of labour relations may reduce the scope for wages and bonuses that are differentiated according to service quality delivered.

IMMOBILITY OF BUILT FACILITIES

In general, services are either delivered where the producing company is located or where the consumer is. Construction as a service is usually delivered at a site determined by the customer. This localization partly explains why the construction frontline often is constituted by subcontractor employees, in contrast to rapid consumer services where customers come to the producer and are served by employees that have gone through in-house training in explicit, standardized procedures, but have acquired little or no experience in handling technical complexities.

The immobility of built facilities is related to the fact that they are often tied to the creation of a technical or natural monopoly such as a large bridge over a river. Infrastructure monopolies of this type are commonly the object of public ownership or other forms of control. Because of this, public procurement of construction services is a significant type of market relationship. Demands on the impartiality of public buying probably explain why contractors use reference projects rather than reference customers in the public sector.

A fixed location is fundamental for the management of facilities, especially the management of negative or positive external effects that the activities of one facility user may have on neighbour users. Frontline staff need broad technical creativity to remedy product faults on the spot, as the profitability of introducing specialized and standardized routines is reduced by the cost of employees moving several times per day between locations. Tacit knowledge of the unrecorded characteristics of a given building can be vital for efficient delivery of services to those who work or live there, and that cannot be provided by a short programme of company training.

IMPLICATIONS FOR CONSTRUCTION PROCESSES

This analysis of how companies have implemented service management practices indicates that the durability and the immobility of built facilities have consequences for how construction and related services can learn from other companies outside the manufacturing sector. In time, we should expect the first wave of uncritical enthusiasm for process quality questionnaires to subside and be replaced by feedback practices that recognize specific features of construction-related services (Bröchner, 2000).

If we look at construction processes as intended to support the core processes of building users and then apply commonly accepted service practices, there is reason to question the goals in terms of just time, cost and (product) quality that have guided the development of innovative construction processes for many years. Instead, there should be more concern with *service* process qualities or, in other words, how the service is delivered to the customer. Therefore, the development of innovative applications of information technology in construction should give priority to features that increase the ability to manage successive changes in construction projects, regardless of whether the initiative for technical changes comes from customers or suppliers of construction services. Mutual communication between project participants, using a wide range of both simple and more sophisticated media, is a key issue when quality dimensions such as empathy and responsiveness are allowed to influence the choice of information technology tools.

In addition, there remains a challenge in reforming the criteria used in public procurement, where the requirements for impartiality when appointing contractors may preserve a situation where excessive effort goes into attempts to provide 'perfect' original specifications and an information technology support for processes based on the assumption that changes should be avoided or minimized during the subsequent process of construction. But customer co-production, in particular co-specification and co-re-specification during the production stage, emerge as a salient feature of construction and construction-related services. IT innovation that supports this type of co-production is liable to have a strong impact on construction activities. This amounts to a plea that construction process models are really to be seen as customer participation models.

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COMPUTER Assisted technologies to enhance CONCURRENce in Building DESIGN

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ABSTRACT

Modern organisms are adapted to a wide variety of habitats and lifestyles. The processes of evolution have led to complex, interdependent, well-designed mechanisms of today's world and this research challenge is to transpose these innovative solutions to resolve problems in the context of architectural design practice, e.g., to relate design by nature with design by human.

In a design by human environment, design synthesis can be performed with the use of rapid prototyping techniques that will enable to transform almost instantaneously any 2D design representation into a physical three-dimensional model, through a rapid prototyping printer machine. Rapid prototyping processes add layers of material one on top of another until a complete model is built and an analogy can be established with design by nature where the natural lay down of earth layers shapes the earth surface, a natural process occurring repeatedly over *long periods of time. Concurrence in design will particularly benefit from rapid prototyping techniques, as the prime purpose of physical prototyping is to promptly assist iterative design, enabling design participants to work with a three-dimensional hardcopy and use it for the validation of their design-ideas.*

Concurrent design is a systematic approach aiming to facilitate the simultaneous involvement and commitment of all participants in the building design process, enabling both an effective reduction of time and costs at the design phase and a quality improvement of the design product. This paper presents the results of an exploratory survey investigating both how computer-aided design systems help designers to fully define the shape of their design-ideas and the extent of the application of rapid prototyping technologies coupled with Internet facilities by design practice. The findings suggest that design practitioners recognize that these technologies can greatly enhance concurrence in design, though acknowledging a lack of knowledge in relation to the issue of rapid prototyping.

INTRODUCTION

Design Research intends to promote a rethinking of techniques in relation to architectural design processes, confronting conventional design practices. Today, through research as well as practice, the role of design and designers in society has been questioned, as well the authority of design action across cultural boundaries. Current research converges around the application of computer technology to design. New computationally based approaches have been developed, creating new challenges for design exploration, including new types of representations, the study of imaging and image synthesis, the use of computational media as vehicles for representation and encoding of design knowledge.

Our research is focused on inquiring into how a broader concern for the environment and the issues of nature can be translated into a set of viable design strategies, forms and technologies at the edge of new directions in architecture. In this research study, we think of architectural design in terms of two different design activities: the *design by human* and the *design by nature.*

The *design by human* process can be defined as the creation of an object representation that meets a set of requirements. During this process, designers take a specification for a product to be designed, which contains a set of requirements the product must satisfy, and generate many solutions to solve it (Figure 1). This is a complex and iterative process where each design solution opens new and possible more complex sub-spaces of design solutions, requiring a wide range of knowledge and expertise. This design activity is described by Archea (1977) as a problem-solving process, a process of 'puzzle-making' where architects search for unique sets of assemblage rules throughout the design process, culminating in an 'internally consistent fit between a specific kit of parts (the architectural elements and the attributes or ideas) and the effects of the blending of all parts, assembled in a certain way'.

On the other side, *design by nature* is the process through which all the organisms dynamically adapt to the external environment and perform its different functions - respiration, reproduction, sensing, movement, etc. This is a process of past-present- and future transformation, because each natural organism is part of a population of similar organisms, but it is also a product of past populations that will supply the future ones. Therefore, *design by nature* can be described as an evolutionary transformation process with a unique goal: the survival of each population of organisms through the correct adjustment to the environment. This kind of design process emerged with the origins of natural life, almost after the Big Bang, and has been optimised throughout years and years of natural evolution. When we study remarkable examples of adaptability transformations performed by natural organisms, provided by sciences such as Biology, Zoology, Botanical, Genetics, Biomechanics and many others, it is evident that *design by nature* is an extraordinary process of fitness coupled with the survival characteristics required by the environment.

Being *design by nature* an optimised problem-solving process performed by natural organisms to successfully respond to the challenges imposed by the natural environment, lessons from nature can be used to support and optimise the other problem-solving processes characterising the *design by human* activity. This process of borrowing the best from nature (Vincent, 1995) has been named *biomimetics* (Vincent, 1995; Jeronimidis, 1995).

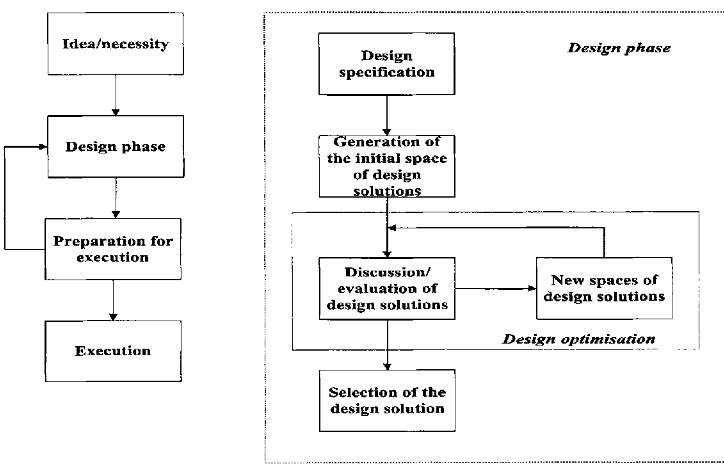

Figure 1 Design activity and product development process.

Our research focus on the new concept of biomimetics, through the investigation of different principles borrowed from the nature that are translated into effective and easily implemented computer tools to support the problem-solving process of *design by human* in the field of architecture.

THE WHEAL OF DESIGN

The 'wheal of design' (see Figure 2) is the name of an interdisciplinary effort, aiming to develop computer-based procedures to complement and strengthen the design process, exploring possible improvements to the cooperative design environment that will take advantage of the various opportunities provided through information technology. Moreover, this research project is investigating different principles borrowed from the nature towards the support of the activity of *design by human* in the field of architecture, as we stressed above. The word 'wheal' is used here in association with the notion of motion, progress, evolution and dynamics, as well in relation to the simultaneous involvement and commitment of all design participants.

Our current research revolves around the application of computer technology to design, involving five different fractions of this wheal of design:

Virtual design: (i) the study of a virtual design environment, through the use of computer-aided architectural design systems, (ii) numerical simulations using the finite element method (FEM) and (iii) optimisation techniques combined with FEM computer codes for material and topological optimisations. Referring to this last issue, we are exploring processes of organic evolution as possible rules for optimisation schemes through the so-called *Evolutionary Algorithms*, representing a class of stochastic optimisation procedures based on the modern theory of evolution.

Rapid prototyping: design synthesis performed with the help of newly rapid prototyping systems using additive techniques. An analogy with the natural lay down of earth layers, which shapes the earth surface, a natural process occurring repeatedly over long periods of time, can be established with rapid prototyping processes.

Research methods: a combination of psychological and statistical methods to evaluate client/user quality perceptions (Bartolo, 2001, Galha, 2000).

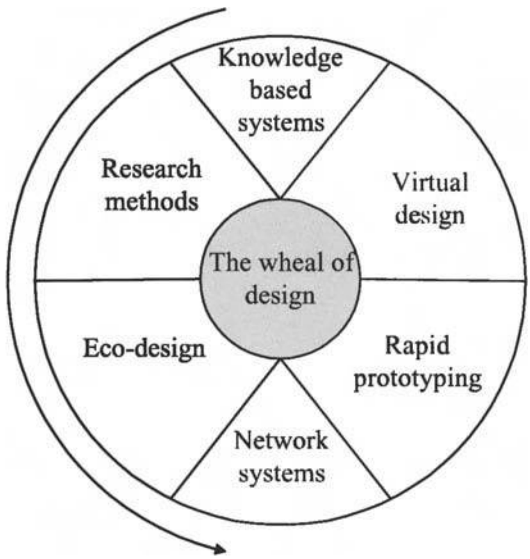

Figure 2 The wheal of design.

Knowledge based systems: the development of design processes through artificial intelligence tools. In this field we are exploring the use of databases of known design solutions to solve new problems. This approach, derived from psychological models of the human memory structure, is based on the premise that humans generally solve new problems by modifying solutions to previously solved problems.

Internet: the Internet use as a multimedia and interactive communication channel to facilitate design collaboration and group decision-making.

This paper presents the results of an exploratory survey formulated to investigate how design practitioners apply different types of technological media, from the physical model through to computer technologies, how they combine the real and virtual aspects of a multimedia design environment, how members of a design team, often geographically dispersed, manage to overcome the barriers posed by distance and different levels of expertise. The preliminary findings of this enquiry are presented later in this paper.

CONCURRENCE IN BUILDING DESIGN

Concurrence in building design requires the simultaneous interact and interplay of all design phases, on top of the co-operation and commitment of all the different participants in the design process (Reddy *et al*, 1993; Tuikka and Salmela, 1998). This collaborative and simultaneous process requires coordination to ensure a reliable exchange of information and an effective reduction of the time and costs of the design phase, on top of a real improvement in the quality of the design product (Bartolo and Bartolo, 2001a,b,c; Bartolo and Galha, 2000).

Many coordination processes require making decisions that affect the activities of a group. For instance, in sharing resources a group must somehow decide how to allocate the resources. Reddy *et al.* (1993) argue that co-decision making implies both the allocation and sharing of responsibilities among participants, and a flexible support for various co-decision making processes. Ellis and Wainer (1994) underline the importance of both the synchronization of activities, the 'activity-level coordination', and the synchronization of concurrent access to shared objects or models, the 'object-level coordination'. Thus, coordination methods are crucial to access common resources, to assure that updates are consistently communicated to all team members and to harmonize concurrent tasks.

A collaboration process is a process where individuals share a common goal and work together towards a common aim. The members of the design team, each with specific key skills, different viewpoints, goals and constraints, must communicate/interact throughout the design process, trying to achieve a balanced solution. Information sharing, common data models and shared data are considered the basic requirements for collaborative work (Reddy *et al.* 1993), but not enough to establish a 'shared understanding' among the participants (Toye *et al.* 1994). Knowledge integration, through collective idea generation and discussion, is also fundamental for an effective collaborative work. Thus, Lonchamp (2000), Poltrock and Engelbeck (1997) highlight the importance for the concurrent design process of a good collaboration and effective information based in a 'co-decision making'.

RAPID PROTOTYPING

Rapid prototyping is a collection of processes in which physical objects are quickly created directly from computer-generated models (Bartolo and Mitchell, 2001, 2000). Figure 3 describes the basic steps required by these systems. The basic concept of rapid prototyping is the layer laminate manufacturing process within which three-dimensional (3D) structures are formed by laminating thin layers representing cross-sections of the digital model created on a CAD/CAM system (Johnson, 1994). The model, which should be an enclosed volume, is tessellated through a process that generates a mesh of triangular elements used to create the sliced model, which contains the set of two-dimensional cross-sections of the model. Afterwards, the sliced model is used to create the physical replication of the computer model by the rapid prototyping machines. Therefore, rapid prototyping techniques are in general additive building processes, similar to 2D printing and plotting technologies using both vector-based and raster-based imaging techniques. The various techniques include laser sintering, lamination, extrusion, ink-jet printing and photolithographic systems (Kai and Fai, 1997).

Rapid prototyping machines, through the generation of physical models quasi-instantaneously, enable all the distinct tasks of the design process to occur almost in parallel, facilitating concurrence in design. Design integration can particularly benefit from these rapid prototyping techniques, as the prime purpose of physical prototyping is to promptly assist iterative design, enabling design participants to work with a three-dimensional hardcopy and use it for the validation of their design-ideas (Bartolo and Bartolo, 2001a,b,c; Bartolo and Galha, 2000).

Rapid prototyping also allows the implementation of a reverse design, facilitating the re-design of an existing product. Through reverse design (see Figure 4), the shape of an existing product is digitised, creating the correspondent surface model, which can then be manipulated (re-design process), and finally the model of the new product can be produced using rapid prototyping techniques. In architectural design, the digitisation can be done using sophisticated computer vision techniques and image-based modelling systems.

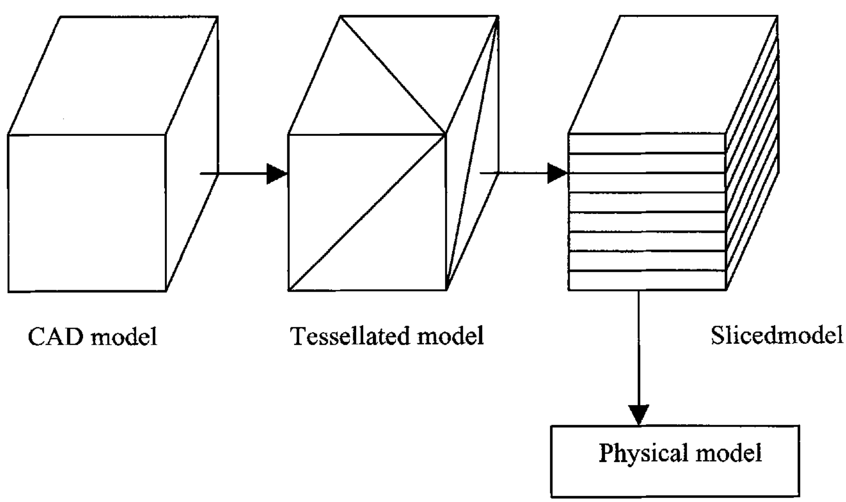

Figure 3 Steps required to produce physical models using rapid prototyping systems.

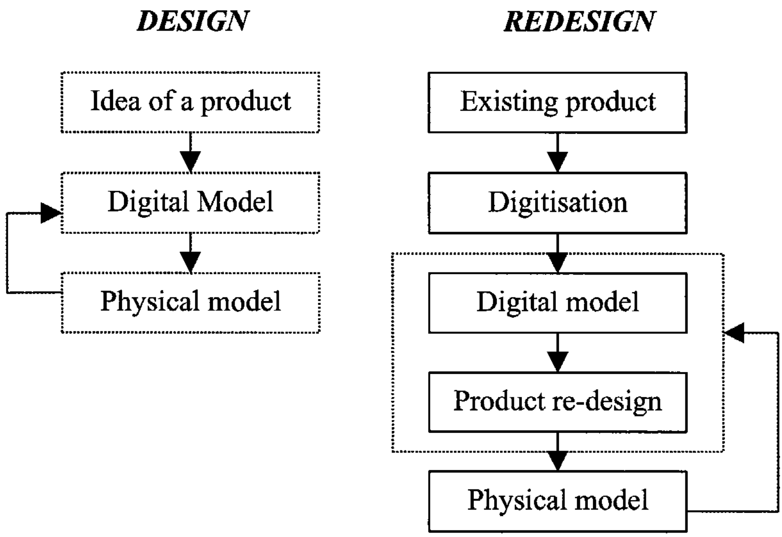

Figure 4 The role of rapid prototyping in a design and redesign process.

Together with the study about the use of rapid prototyping systems as tools to enhance collaboration, concurrence, commitment and quality in architectural design as described in this paper, our group has been involved in research regarding the development of new and improved rapid prototyping systems under the project LRAM (Leiria-Reading manufacturing programme, see www.rdg.ac.uk/psc/lramp.pdf) and the project "Two photon writing processes in organic polymers", both supported by UK funding.

THE INTERNET TO FACILITATE DESIGN COMMUNICATION

Today, people use the Internet as a powerful multimedia and interactive communication channel to engage in a new kind of information exchange. This exchange of information can involve different types of digital media, such as text, image, video, and audio. The introduction of an IT- networking environment in architectural practices will enable new ways of digital working partnerships to emerge, exploring the opportunities generated by media technologies. Finch and Luebbe (1997) report that design professionals use these media technologies within their design offices (local network systems such as Ethernet) or among international sites (world network systems such as the Internet). Design studios can promote group projects among geographically dispersed teams, enabling both the communication through a distributed virtual prototyping system and the interaction in real time by distant design teams. Videoconferencing facilities can enable a face-to face interaction, facilitating the development of new concepts combined with emerging communications media (Maxfield *et al*, 1998; Sariyildiz *et al.*, 2000). To manage and synchronise this process of information technology, the architecture for computing, communication, and electronic information must be robust, coherent and integrated (Tuikka and Salmela, 1998), on top of being cost-effective to use, operate, and support. Moreover, the association of the Internet and local Ethernet network systems with rapid prototyping machines will facilitate a "mutual understanding", facilitating collaborative design and group decision-making.

METHOD

An e-mail questionnaire was formulated and sent to a geographically dispersed sample of design practitioners to understand how designers approach three-dimensional synthesis using the speed and accuracy of the computer coupled with the physical models produced by a rapid prototyping machine, as well to perceive how useful these new technologies can be to achieve an effective participation of both the client/user and the constructor/supplier throughout the design process.

This ongoing e-mail questionnaire is divided into four sections, concerning the following issues: (1) personal details of the design practitioners and characterisation of the design firm, (2) to assess of the effective usage of CAD technologies by design practitioners, (3) to identify the level of knowledge in relation to rapid prototyping technologies, the degree of its use and its importance for design processes and finally (4) to understand the importance of the Internet tools for the design process.

RESULTS

The findings report the analysis of 150 questionnaires received, from Australia, Brazil, Canada, France, India, Iran, Italy, Netherlands Portugal, Spain, South Africa, USA and UK.

On section 1, the design practitioners were asked for information on their academic degrees, professional skills and business where they worked, besides some personal details such as gender and age. From our sample of returned questionnaires, 75% are architects and 25% industrial designers, with a male percentage of 71, distributed as following: 38% (aged from 25 to 34), 35% (aged from 34 to 44) and 27% (aged above 44). Most of the answers, 71%, came from small firms with less than 50 employees, while 18% work in companies with more than 100 employees. In Section 2, the design practitioners were asked to answer several questions on CAD systems, to understand how their organisations use them, to what purpose and what kind of difficulties were experienced.

The answers acknowledge a widespread usage of CAD systems. Designers currently use these systems to produce working drawings, prime presentations, design approvals, 3D renderings and animations. Most of designers (78%) use CAD to create both 2D and 3D design representations. It is apparent that the creation of 3D models in CAD is widespread, which is an important finding emerging from this exploratory study. If designers can easily create solid models, then they own the necessary skills to use RP systems. Consequently, RP systems could be integrated into the design environment just as conventional printers are used today. Though a large amount of designers, 81%, use frequently CAD systems as a tool to communicate with the client/user, a significant proportion of respondents, 63%, have experienced difficulties to communicate with the client/user, corroborating other findings from other studies (NEDO, 1983; Peng, 1994 and Sonnerwald, 1996). Clients/users major difficulty appears to be the understanding of design representations produced by CAD systems.

In section 3, the design practitioners were asked about their knowledge and usage of rapid prototyping technologies. They were also invited to express their view on potential benefits of these systems in terms of client/user involvement, quality of the design product, time to achieve a good design solution, costs, etc. Only 35% of the designers claimed to know RP technologies though, through their subsequent answers, it was found that the respondents (54%) perceived rapid prototyping and conventional CAD/CAM systems as similar systems. On the other hand, 81% of all respondents believed its introduction in the design process would be beneficial. This was an interesting finding, apparently recognising the need to divulge RP technologies among design practitioners, possibly through its introduction in architectural curriculum, similarly to what had already happened with the inclusion of RP issues in engineering curriculum. Moreover, it seems that the great majority of architectural firms frequently use model makers to produce their physical models, spending too much time and money in this process, between two and ten weeks, according to the complexity and size of the model. The main advantages of the use of RP technologies in architectural design studios are indicated in Table 1.

Section 4 relates to the use of the Internet tools. The great majority of architectural firms (54%) frequently use both local and world network systems all through the design process. Moreover, most designers (82%) use the Internet facilities to communicate with clients/users realizing its potential to change design processes. The main advantages and disadvantages of the Internet facilities in architectural design practices are indicated in Table 2.

CONCLUSIONS AND FURTHER RESEARCH

Concurrent design involves the interaction between diverse 'cross-functional' teams of individuals who may be scattered over a wide geographic range. To integrate design requires the skills of many designers and experts, where each participant creates models or tools to provide information to other participants. Information sharing and activity synchronisation have key roles into the concurrent design environment. It is vital to develop a new design approach to overcome the barriers posed by distance and different levels of expertise. Advanced computer design representation packages, rapid prototyping and network technologies can play a key role in this new approach.

This concurrent approach will imply that designers, clients/users and constructors to be involved from the very beginning of the design process. Thus, interaction between the activities of design and construction management will be possible with advantages in terms of time, costs and quality. In this paper we have only explored the influence of concurrence in design. Future research will address the impact of concurrent design over the construction management activity.

The questionnaire results suggest a high level of agreement relatively to the importance of using innovative techniques to rapidly produce physical representations of the design idea, as it would enable designers to make physical models directly from CAD models, though the deficient knowledge of RP technologies by design professionals is considered an obstacle for their actual use. Moreover, the results show that the Internet is understood by designers has a restriction to creativity because of its deficit in human contact. This exploratory study was important not only to identify the extent of the knowledge and effective application of rapid prototyping technologies by design practitioners, but also to use as a benchmarking tool for the next stage of the research. The next step involves the development of a computer network system using RP technologies towards the implementation of a concurrent design environment.

Table 1 Advantages of Rapid Prototyping in the Architectural Design Environment

Client/user involvement	**Time to achieve the best solution**
• Facilitates the conceptual design phase, helping the design creative process • Promotes ownership and commitment • Improves client/user confidence and motivation • Enables to enhance design reviews	• Faster • Quicker changes • Reduces time to achieve a solution • Improves the decision making process
Communication between the design team, the client/user and the constructor	**Costs**
• Better communication and coordination of information • Improves integration among different disciplines • Makes easier to explain design details • Beneficial especially to assess the design merit of a scheme • Enables a mutual learning process	• Effective cost reduction
Quality of the design product	**Other benefits**
• Better end products • Enables more testing • Representation is closer to the real design product • Will allow designers to produce multiple options, enhancing creativity	• Enhances designers enjoyment and satisfaction • Risk reduction • Useful for different types of presentations • Better understanding of design details

Table 2 The Internet Facilities in the Architectural Design Environment

Advantages	**Disadvantages**
• Speed of communication • Improves dissemination of ideas • Enables remote collaborative work • Important tool for benchmarking • Improves the design time • Provides more resources	• Reduces human contact • Isolation • Dilutes creativity • Security • Time consuming to exchange "heavy" image data-files

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The Identification of Project Risk

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INTRODUCTION

There are many definitions for the terms 'risk' and 'risk management'. For the purpose of this paper, the definition of risk management as given by Remenyi & Heathfield (1966) is taken to be appropriate: "The possibility that the actual input variables and the outcomes may vary from those originally estimated". Implying that the extent of the possible difference between the actualities and expected value reflects the magnitude of the risk. Many large public and private organisations have risk management procedures and employ a formal Risk Management Process (RMP), either one of their own or developed from a methodology or a guide. However, research has revealed that Project Risk Management has not been fully embraced by project organisations.

Chapman and Ward (1997) state that many experienced project managers perceive a gap between good practice as advocated in project management textbooks (theory) and good practice as they have experienced/perceived it. It has been recognised that this may reflect a collective failure of the project management profession to define comprehensively the approaches to project risk management that are fully integrated with project management. Concern has been expressed that steps need to be taken to fill this gap. Flanagan and Norman (1993) state that "managerial techniques used to identify, analyse and respond to risk have been applied to the construction industry only in the past decade", and that "...there is a gap between the theory and techniques proposed to manage risk and what people actually do in practice".

The aim of the research (2000) was to investigate risk management theory and practice, to discover why there may be a gap between them and from this to develop a model that can be useful to project management organisations not currently using a formal RMP when considering matters of project risk. The map takes the form of a project management and risk matrix and is the subject of this paper. It allows the user to appreciate where project risks lie, those who can be responsible and where effective management response will benefit a project's outcome.

CONCEPTS OF A PROCESS MAP

The results of the research show that the smaller project based organisation has a potential for improving its commercial position within the industry by the use of a formal Risk Management Process (RMP) which should take a form that can initially highlight high level risk issues. The literature review and research into risk management theory reveals a powerful knowledge base that may remain largely untapped by industry.

A mapping of project criteria allows the user to explore project risk issues and use their skill and experience to evaluate real threats and opportunities. This can be amended as the project proceeds and the risk position changes. A textual support to the map takes the form of a high level prompt based on current risk management theory. It is intended that this 'add-in' theory compliment the skill and knowledge of the project management organisation, allowing an informed project management plan to be developed and implemented.

The model that is designed includes recognition of:

- Those project based organisations not currently embracing a formal RMP.
- The intention that the understanding of project risk mapping is to be embraced by the whole organisation.
- Certain mathematical principals that must be understood if attempting to evaluate project risk in terms of cost and time.
- That an organisational culture that understands the principal of risk and return in terms of 'objective' and 'perceived' risk will have an advantage where a level of 'risk efficiency' can be agreed.
- That risk mapping is designed to be treated as an 'add-in' to an organisation's normal management procedures.
- That, as people and individuals are central to risk management, those accountable, responsible and best able must be identified and named.

It is intended that the model produced can help bridge the gap between risk management theory and what is actually done in practice.

DESIGN OF THE RISK MODEL

The risk model must therefore be designed so that it is constructive and describes a real project risk scenario whilst retaining, as far as possible, a high level of transparency that will require simplicity of presentation. It was realised that this would not be an easy task as the mapping would be required to aid in understanding project risk on several fronts. It was decided to break the problem down into its various components and see how these could be grouped together for diagrammatic purposes.

The map should be easy to understand by those who are interested in project risk management and who wish to ally current theory and risk management practice. The components of the maps (to be diagrammatically represented) that have been identified are as follows:

The project Functional Breakdown Structure (FBS)

A breakdown of the project's function will be closely associated with the business case, it essentially shows how the project is designed to meet its aim and objectives. There will be named organisations and/or individuals that will be accountable or responsible for the concept, planning or ownership of the project function and they will need to be identified.

The Product Breakdown Structure (PBS)

This is essentially a description of the physical nature of the project. It details the project components in terms of 'the bricks and mortar'. Again, there will be organisations and individuals that are accountable and responsible for its various components.

The Work Breakdown Structure (WBS)

This is closely related to the PBS in that it details a breakdown of the method of construction. It will include for example a description of civil engineering work, electrical work and mechanical fabrication work required as well as the method for contracting. As with all other aspects of the project, organisations and individuals are central to the function.

A Systems Breakdown Structure (SBS)

This can sometimes be considered as a separate project component from that of the product or the work that needs to be done. It tracks an operational function. For example the air conditioning in a supermarket could be described as a system although it would be purchased and installed as part of a broader mechanical and electrical contract within the overall project.

The Cost Breakdown Structure (CBS)

Details the spread of finance. This can be shown for both the product and the work required.

Risk relating to the Project Life Cycle (PLC)

This is presented to show the varied risk issues that need to be considered as the project progresses.

The Project Base Plan (PBP)

This ties the whole business case together and provides the basis of understanding on how the project can provide the intended level of benefit within the period of the investment.

Risks

Finally, the risks as they may apply to each of the above project considerations may be broken down within themselves. Risk can be considered under four headings; Project and Business Management Risk, Financial Risk, Corporate and Organisational Risk and Technological Risk.

In providing support to the map, it will be necessary to advise on risk attitude in terms of:

- Questions that need to be asked at each stage of the risk management process.
- Consideration of potential risk factors (a generic view).
- Method most suitable for quantifying risk exposure.
- Risk efficiency.
- Practical risk avoidance.
- Team/individual capacity/skill/experience.
- Organisational power base.

CONSTRUCTION OF THE RISK MODEL

The model is designed so that it can inform on areas of potential project threat and opportunity and in its diagrammatic form contain all the components previously identified.. The amount of information that needs to be represented is large and it was recognised that mapping could not be contained within a single page. It is thought that a computer representation of the map and support information could be made, but it would exist outside the scope of this research and may form the subject of further work. The decision was therefore made to construct a series of diagrams that would represent each project area that could be exposed to risk. Even these diagrams will only show a high order of events but this was not considered to detract from the conception value.

In addition, it was decided that the whole map would not be *generically* described, but would be explained in the form of a 'cases study project'. Support notes could however be generically described.

The stages in constructing the map are:

(i) Group together, for each part of the project structure, a representation of the risks that may be applicable together with a representation of organisational structure/responsibility.

(ii) Match each risk to an element of the project structure and to named individuals for each project participant organisation as well as other stakeholder interest where applicable.

(iii) Summarise the information gathered on each diagram and consider the potential for correlation and duplication of risk areas and areas of opportunity.

(iv) Compile the map support notes. These will include:

- A qualitative view on practical risk avoidance and contracting.

- A view on why the map should be regularly revisited as the project proceeds.

- The consideration of risk efficiency and corporate attitude to risk. This will include advice on the requirement that risks be valued in terms of cost and time impact very early on, even though this may be a rough estimate.

- Notes on the value of a basic understanding of quantitative risk analysis.

- A consideration of the natural ability of individuals that will be of maximum benefit to the organisation when managing risk (the value of psychometric profiling).

An example of a Map diagram appears as Figure 2 at the end of the paper and this follows the basic format of Figure 1. The logic of the map is worked through in the next section.

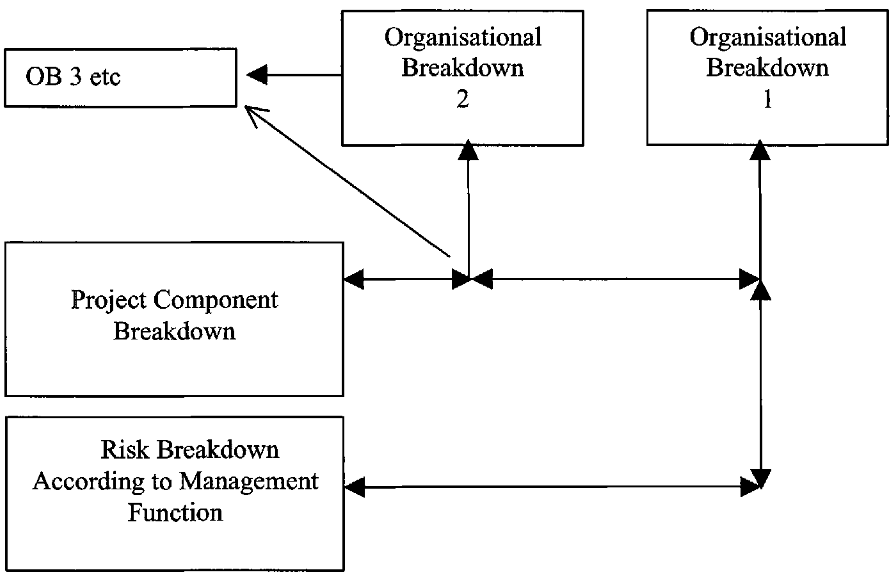

Figure 1. Basic format of a holistic risk identification map.

The proposed approach to risk identification and management using the risk maps is as follows:

Step 1.

Obtain a general consensus as to loss or opportunity associated with the project, remembering that in the case of loss situations associated risks will be of two classifications, those that can be influenced and those that cannot. This will be a high level appraisement and will point the way in selecting those individuals who might best provide quality information on the risk position.

Step 2.

Identify within the project breakdown where risk may exist. This is promoted to be within those areas of:

- Organisation Breakdown Structure (OBS)
- Function (FBS)
- Product (PBS)
- Work (WBS)
- System [where applicable] (SBS)
- Cost (CBS)
- Project Life Cycle (PLS)
- Project Plan (PBP)

Step 3.

Decide how the risks can be described in terms of:

- Project Management and Business Risk
- Financial Risk
- Corporate Risk
- Technology Risk

Consider the risks as 'perceptive' or 'objective'. This is important if a suitable method for risk quantification is to be chosen.

Step 4.

As part of the OBS enquire as to whom within the project organisation is likely to be involved in potential risk areas and contemplate their skills and experience. Where the skill base can be influenced this will require appropriate action (training and resourcing) and where this cannot be done (outside participants and stakeholders) it should be noted as a risk area in itself for management.

Step 5.

Examine all project participants and outside stakeholders identified as part of the OBS. Enquire as to what it is that the parties want to achieve as an end result and what it is that they might be interested in as part of that end result. Threats and opportunities for influence can then be emphasised.

Step 6.

Having made a list of risks make a judgement as to the chance that a particular risk can occur. Understand this in terms of 'a priori probability', an 'estimate of actual frequency' or a 'judgement of credibility'. Decide then if the probability can be identified between those involved in terms of:

- "Yes there is a risk"
- "Yes there is a risk of a % certainty"
- "Yes we could loose production or be affected in some way if it occurs"
- "Yes other participants and stakeholders will be affected if it occurs"

Or any combination of the above and a level of risk can then be initially agreed.

Step 7.

Note that each risk event will have a cause and an outcome. There is a likelihood that each cause will lead to the event and a further likelihood that the event if it occurs will result in each of the outcomes. The object of an initial risk assessment is to manipulate a risk to a position where it is known to have a potential for influence from one of total uncertainty.

Step 8.

Use appropriate techniques to quantify the risk. It is necessary to understand the 'nuts and bolts' of risk analysis techniques if one is to appreciate a holistic view when using these methods. Risk quantification techniques can be described as qualitative, quantitative and control. Beware of bias when estimating and note the limitations of describing a risk in terms of probability multiplied by impact. This method, although very useful, is simplistic and a good understanding of the risk potential is essential.

Step 9.

Consider how individual risks interact in terms of sensitivity and correlation. Consider the overall generality, volatility and uncertainty and the combined effect of risk (the overall riskiness). This is where computer software using simulation has been shown to be useful on complex risk analyses.

Step 10.

In the light of the risk information that has been gathered and the risk calculations made, consider the actions that will benefit the project or limit losses.

Step 11.

In considering a 'Risk Competent Path' decide on the control actions that could be made in terms of:

- Modify the objectives
- Avoid the uncertainty (insure or do things differently)
- Prevent (change the probability of uncertainties)
- Mitigate (modify the impact of the uncertainty)
- Develop contingency plans
- Keep your options open
- Monitor
- Accept
- Remain unaware – do no risk analysis.

Step 12.

Enquire as to the position regarding the availability of resources to manage the ventures identified on the 'Risk Competent Path' (cash, human, plant, materials, organisational support and reputation).

Step 13.

Consider when the necessary actions need to be carried-out.

Step 14.

Question how the various risk responses on the path can be achieved. This is the design of the Risk Management Plan (RMP).

Step 15.

Calculate how much the risk responses will cost both in terms of implementation and impact on the whole project (loss or gain).

Step 16.

Choose which Risk Competent response is appropriate. Remember that bias and human/organisational behaviour should be monitored throughout the whole process.

Step 17.

Complete the RMP.

Step 18.

Obtain support for the proposed actions at the highest level. This should be formalised.

Step 19.

Be aware that the best individuals and teams will be required to implement the RMP. If these have not already been satisfactorily selected then consider an organisational friendly type of psychometric observation such as Myers-Briggs or Belbin and bring individuals together to discuss results.

Step 20.

Implement the RMP.

Step 21.

Review the plan and the selected risk response viability regularly and apply the model again at each review.

CASE STUDY PROJECT

A project scenario to explain the risk mapping is a project for the provision of a new supermarket outlet on a green-field site where it has been decided that this will result in increased profits for the organisation. Contractual arrangements will be via a standard management type contract. For each project criterion a map is created (5 maps in all). In addition maps are created showing risk through the project life cycle and risk relating to the project base plan. Each map refers to input of risk information relating to the relevant project criterion, the breakdown of risk and the project organisation. Risks relating to the project criterion of the Product Breakdown Structure (PBS) have been chosen to demonstrate the mapping for the purpose of this paper. Three potential risks have been promoted and the relationships to other project criteria are shown by the arrows in Figure 2.

A Financial Risk relating to the possibility of changes to the product are seen to exist to the building structure and the fitting out of the interior. This has the potential for serious consequences and essentially the owner and his agents are the only project participants who can authorise such changes. The contractor will be concerned as to changes to the project, they may be profitable if paid for at a fair price but could be disastrous if ordered as a result of some contractor misinterpretation.

The Technological Risk of the possibility of an inadequate design of the security system must be recognised. The owner's consulting engineers must be responsible for ensuring that a system with the correct specification and performance criteria is supplied.

The Business Risk to late delivery of refrigeration equipment can be crucial. Contractors will put themselves in an unacceptable contractual situation if they fail to deliver as specified. The owner's representatives should not be oblivious to this late delivery that will also pose a threat to their client.

CONCLUSIONS

The risk mapping represents a way of 'thinking about risk' (it is not the teaching of a method of risk analysis). It allows organisations that are not currently using formal methods of project risk analysis and management to systematically think about how they can improve their situation in the business and project environment.

The mapping shows the value of recognising project risk in terms of a formal analysis that draws on risk management theory. However, it is intended that the framework for analysis (the building of the risk maps) be the result of a specific organisation's special skills and experience. By combining theory with the peculiarity of those skills and experience associated with good project management practice and expert knowledge there is a good chance that adverse project risks can be reduced or removed and opportunity realised. It is considered that in this regard, the research and the mapping described can assist in bridging the gap that has currently been seen to exist.

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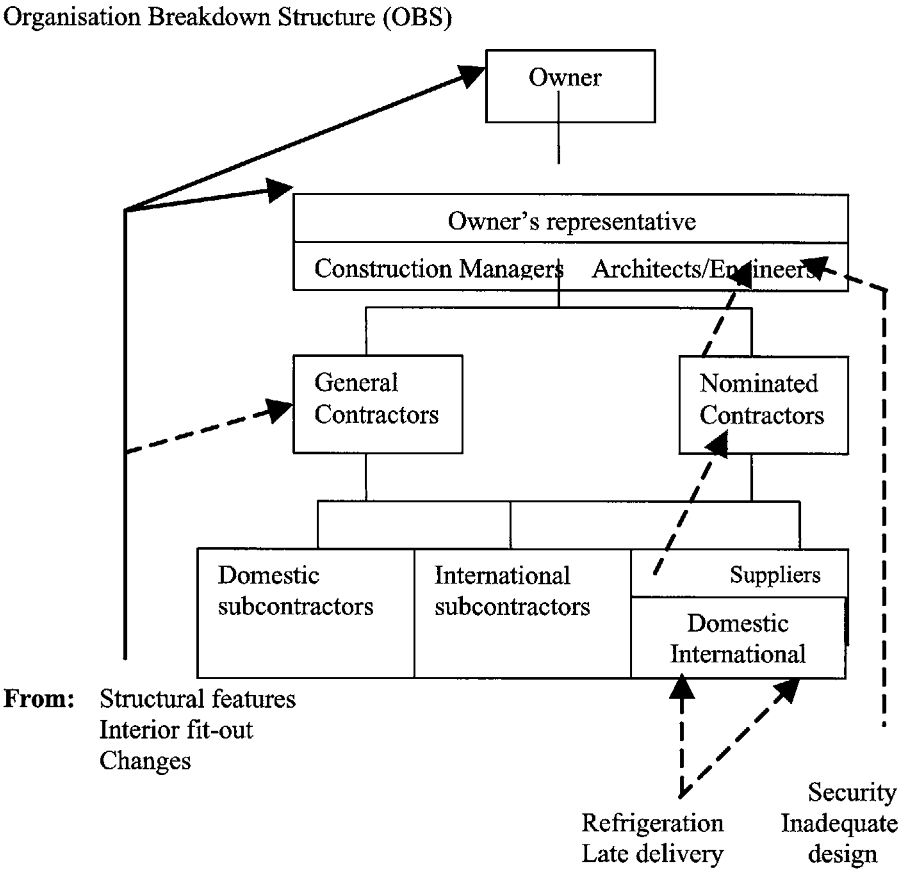
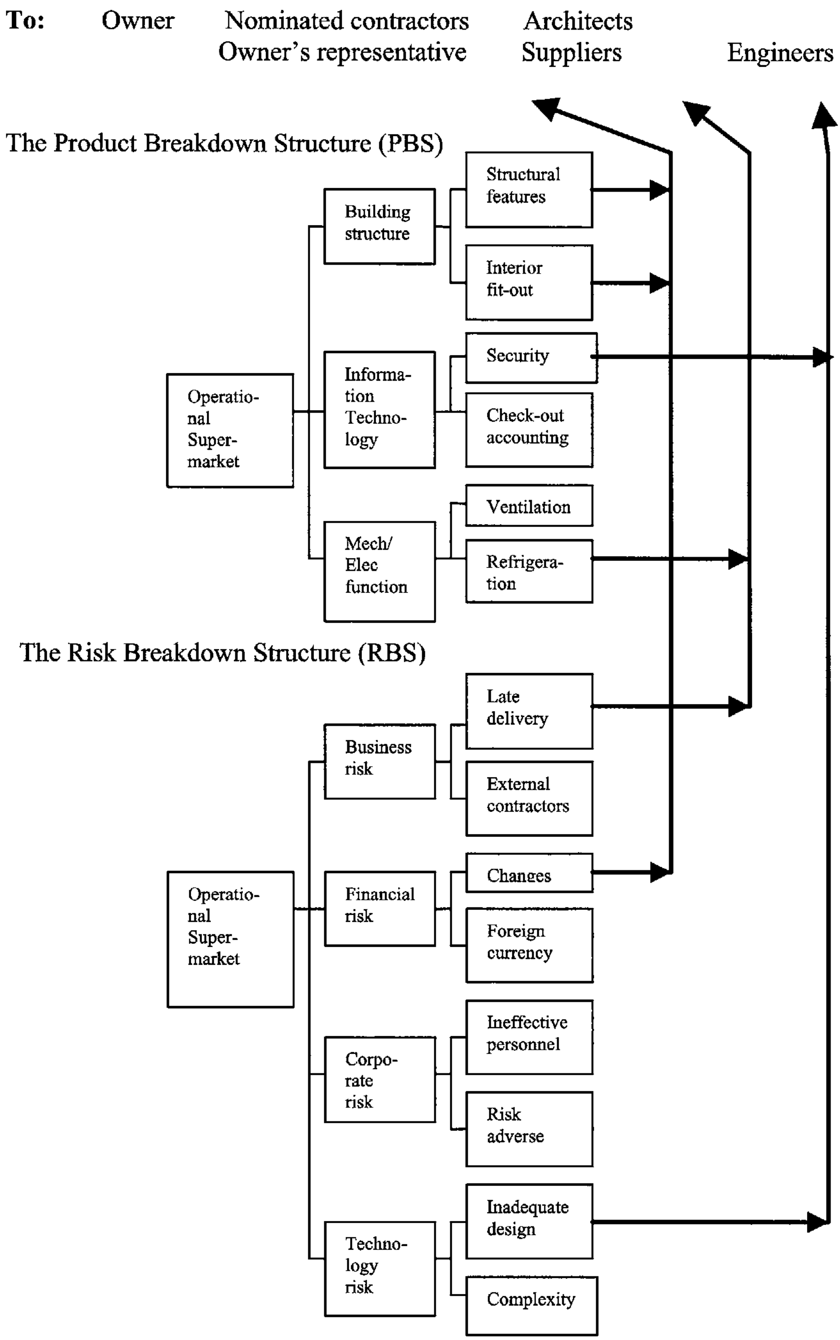


Figure 2. Risk liability and responsibility for the "product".


To:
Owner
Nominated contractors
Owner's representative
Architects
Suppliers
Engineers
The Product Breakdown Structure (PBS)
Operatio-nal Super-market
Building structure
Structural features
Interior fit-out
Informa-tion Techno-logy
Security
Check-out accounting
Mech/ Elec function
Ventilation
Refrigera-tion
The Risk Breakdown Structure (RBS)
Operatio-nal Super-market
Business risk
Late delivery
External contractors
Financial risk
Changes
Foreign currency
Corpo-rate risk
Ineffective personnel
Risk adverse
Techno-logy risk
Inadequate design
Complexity

Knowledge Management for Project-Based Learning in Construction

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ABSTRACT

Project-based working in construction poses significant challenges for the development of appropriate strategies and practices for the capture and diffusion of knowledge and learning. Drawing upon research conducted in the UK into knowledge management for project-based learning across a range of industrial sectors, this paper presents a case study of knowledge management practices within a construction company. It examines the key enablers and barriers to the effective capture and diffusion of knowledge and sets the discussion of the construction case against the findings from the research as a whole. The analysis stresses the importance of social factors in understanding and, ultimately, enhancing knowledge management capabilities in the construction sector.

INTRODUCTION

Knowledge management (KM) strategies and practices have become an increasingly important way in which companies have sought to develop their innovative capacity by increasing their ability to retain and apply knowledge and learning. However, in the construction industry the importance of project-based working creates many challenges for the development of appropriate KM strategies and practices. 'Re-inventing the wheel' becomes hard to avoid because the cyclical and discontinuous nature of project activities inevitably creates significant discontinuities in personnel, behaviour and information capture. The fragmentation of the construction project team into different professional disciplines also creates difficulties, since different disciplines have their own knowledge-bases and languages and this can make the effective codification and transfer of knowledge even more problematic.

Although a good deal of knowledge within organisations may be amenable to the application of IT-based tools and techniques, approaches to KM have increasingly stressed the importance of the *social community* in promoting or inhibiting knowledge retention and transfer. In this approach, emphasis is placed on the tacit dimension of knowledge and its embeddedness within particular social groupings and situations. Understanding architectural know-how, for example, depends not only upon technical expertise, but also upon the ability to access a host of surrounding assumptions and meanings. Such knowledge is, moreover, difficult to exploit even when clearly articulated, because it requires a shared system of meaning for understanding, accepting and deploying it.

This paper reports findings from an Engineering and Physical Sciences Research Council (EPSRC) project designed to explore KM for project-based learning in a UK construction company (grant reference GR/M73286). The research as a whole sought to compare and contrast KM practices across a range of industrial sectors in which project-based working is common, but where project tasks vary significantly (pharmaceuticals, telecommunications and health). Consequently, the paper sets the findings from this company in the context of lessons learnt from the research as a whole. The aim of the research was to identify likely enablers and barriers to effective capture and transfer of knowledge for learning across characteristically different project environments. The main findings from the research highlight the importance of social factors in enhancing knowledge management capabilities in construction, as well as other, project environments.

KNOWLEDGE MANAGEMENT AND PROJECT-BASED LEARNING

On the face of it, project-based organisation – characteristic of much construction activity – significantly enhances the innovative capability of the firm by increasing flexibility and opportunities for cross-functional learning (Bolwijn and Kumpe, 1990). Seizing these advantages, however, involves overcoming significant barriers to the capture and recycling of project-based learning. These barriers arise from the distinctive character of project work - self-contained tasks that are highly discontinuous on a number of dimensions (personnel, time, space, information flows). The resulting problems of transferring knowledge across projects or between different project phases mean that the tendency to 'reinvent the wheel' is all too common in project work. However, developing the capability to effectively manage knowledge across projects is an increasingly important source of competitive advantage – not only in construction, but also across a wide range of sectors (Scarbrough et al, 1999; Nonaka, 1994).

Overcoming barriers to effective knowledge management (KM) involves a range of interventions. To date, tools and methodologies for KM have adopted a *cognitive* model of KM whereby valuable knowledge can be codified and circulated more widely through the application of information communication technologies (ICTs) (Cole-Gomolski, 1997). However, this model has been challenged by studies that question its emphasis on knowledge codification through technology (Spender, 1996; Swan et. al, 1999). More recent approaches have stressed the need to adopt a *community* model that focuses on the tacit dimension of knowledge (Sanchez and Heene, 1997). This assumes that knowledge transfer involves developing some level of shared meaning that allows one group to understand and apply another's insights to their own context (Weick, 1995; Spender, 1996; Senge, 1990).

The importance of shared meaning, however, highlights the problems of inter-project knowledge transfer between groups that are spatially and culturally differentiated. The community model emphasises the importance of social networks and the cultivation of trust, norms and shared values amongst 'communities of practice' (Brown and Duguid, 1996). These social processes impact upon the organisation's ability to manage knowledge via the use of ICTs (Pan and Scarbrough, 1998; McLoughlin, 1999). They are also influenced by the wider institutional and organisational context (Teece, 2001). For example, the barriers formed around networking associated with professional demarcations and/or contractual considerations. At the individual level, incentive structures may influence the willingness of individuals to engage in knowledge capture and transfer practices (Keegan, 1998). Thus, the community model highlights the extent to which the creation, transfer and application of knowledge is influenced by the context of practice (Pavitt, 1984).

Taken together, the cognitive and community models indicate the range of dimensions and interventions that may be important for the capture and transfer of learning, and the mediating role of organisational and institutional context in the effectiveness of such interventions (Teece, 2001). Critical enablers and barriers to managing knowledge for project-based learning may vary across sectors. That said, although organisations may produce different products, they may well share similar characteristics and therefore similar problems in their *processes* for managing knowledge. There is therefore potentially considerable benefit in exploring knowledge management for project-based learning in construction in the context of developments occurring across industrial sectors.

METHODOLOGY

The research reported here was part of an EPSRC-funded scoping study, which explored knowledge management for project-based learning across five distinct sectors in the UK (construction, telecommunications, pharmaceuticals, health and social services). Since this was a scoping study with limited resources, the unit of analysis was a focal project (or 'project probe') in five organisations, each representing one of these sectors. All of the projects concerned the development of new products/services and/or new organisational practices. On average, seven interviews were conducted per case with key project team members. Interviews addressed the generation and capture of learning within the project and inward/outward knowledge transfer to and from other groups in the organisation. The case study presented below is of a new initiative within the construction firm. In the later discussion, the findings from this case are set in the context of the findings from the research as a whole.

The Regional Engineering Manager (REM) Project

This project involved the introduction of a new role – the Regional Engineering Manager (REM) – into a regionally-divisionalised construction company. The aim of introducing the new role was to contribute towards profitability by increasing the value engineering of projects, as well as to improve the coordination of engineering services provision and engineers' training and development across the regions. The REM was therefore seen as a conduit for the spread of engineering-based knowledge and project-based learning throughout the company.

THE CONTEXT OF THE PROJECT

The construction company was a national contractor with an annual turnover of about £370m, consisting of £160m of building work, £150m civil engineering work, £40m of marine/water work and the rest in small projects and heavy plant provision. The company was split into four regions – the region from where the research was conducted employed about 1,200 staff. They used very little direct labour and employed regular consultants to provide design services. Over half of their work was done on a design and build basis.

The REM was a position established 5-6 years earlier to facilitate communications among the regional offices and between the regional offices and the sites; and to assist with the tendering process, particularly in the area of value engineering. There were 10 REMs in total – two in each region (one building, one civils), plus two in group companies. The creation of the REM role was part of a broader internal 'transformation process' that began in 1994/5, and which saw the company attempt to change from a more adversarial approach to contracting to a more collaborative style. The REM was to contribute towards putting together tenders, to value engineer tenders and existing projects, and to assist with the training and development of site engineers. The REM did not directly manage any site engineers or other staff. It was envisaged that the role would provide a career route for engineers who did not want to develop their careers in management positions. The role needed to be cost effective, as the costs of employing 10 REMs in the business amounted to about £0.5m per annum. Although financial savings targets were originally set, REMs now performed according to a list of 12 expected 'results', which varied from the general (e.g. expecting them to be 'leaders within every business') to the more specific (e.g. establishment of a register of expertise).

The REM role had not been without its problems and early difficulties were encountered in setting out a clear job description and in selecting appropriate staff. These problems had now been solved, although there are still tensions in the role which stemmed from differences between regions and differences in the emphasis put upon different parts of the job. In particular, there was a tendency for REMs to be more involved in the value engineering part of the role than in the longer term, more developmental aspects of the role where outcomes were less immediate and tangible. The lack of direct control over staff also meant that, to get things done, the REM had to matrix manage site engineers. This could cause them difficulties in getting their objectives accomplished and also meant that the REMs relied on a supportive climate to get others to assist them in their work. A further consequence was that their success depended significantly upon the skills and aptitudes of the person doing the job (especially communication and interpersonal skills).

NETWORKING AND MODES OF COMMUNICATION

The REMs in particular and the engineers in general relied heavily upon networks of personal contacts throughout the firm and beyond. Email was used extensively, but so were other more traditional forms of direct contact. Although the company had an internal register of expertise, personal knowledge of whom to contact was more important. REMs also met together every three months at 'engineering forums' to discuss issues. They also arranged bi-annual forums for engineers. Contact with engineers on site, to provide technical support and career advice, was frequent and informal, but sporadic and largely in response to queries raised. REMs were less involved in formal project progress meetings, although they were more involved in pre- and post-contract meetings, including value engineering workshops. Through these, they had opportunities to communicate with clients and other external organisations.

Although the company had a solid IT infrastructure and used e-mail regularly, the company Intranet and the engineering database it contained was not well used. Apart from the lack of a standardised system, there were no incentives or resources to keep a centralised database up-to-date and accurate. As a result, there was still a very strong emphasis placed on direct, face-to-face contact and other, more traditional ways of communicating and transmitting information across the company.

ENABLERS AND BARRIERS TO KNOWLEDGE CAPTURE AND TRANSFER

To summarise there were a number of key factors that acted as enablers and/or barriers to the capture and transfer of knowledge via the REM role. First, there were *Organisational Structure Effects*. The drive to establish the REM role came from an established group at the centre and the location of the change project within the one discipline (engineering) meant that any problems associated with communication across interdisciplinary boundaries were avoided. The size of the company itself enabled economies of scale in the use of certain mechanisms that encouraged cross-regional and cross-project knowledge transfer (e.g. the engineers' forums and training programmes).

On the other hand, in the early stages at least, REMs faced a lack of clear definition of roles and responsibilities. This role ambiguity could lead to a 'regression' to a more traditional engineering support role and the tendency for short term business concerns to take priority over longer-term developmental needs. Certainly divisional directors' expectations of the role varied in practice and immediate workload pressures often took precedence. Moreover, since the REMs employed no direct staff (and would be unlikely to be able to justify more help), REMs had no line authority over engineers and there was a lack of incentive to feed information back to the REM, other than on an as-needed basis. A heavy reliance was placed upon the REM being proactive.

Second, *Culture, Politics and the Climate for Change* were important. It was important that there was a 'champion' in getting the change introduced in the first place and then developing it further when there were early problems. Continuing support across the company as a whole was also important. Although REMs were expected to achieve a lot in terms of 'bottom line' results, it was clear that the climate for change was supportive and the company was generally receptive to the idea and to the business case made (and had recently relaxed financial targets). On the other hand, the level of support did vary between the regional companies, especially during the early stages. Moreover, there were still considered to be "pockets of resistance" and some concerns were expressed that recent restructuring changes would have (unspecified) implications for the role.

Third, the importance of the personal *Skills and Capabilities* and the styles of those occupying the role meant that REMs had considerable latitude in how they performed their role. On the other hand, it meant that a lot still depended upon individuals' social contacts and informal networks (as well as their enthusiasm and personal skills in developing them). It also meant that the company had needed to recruit from outside, thus reducing the intended internal career opportunities that the REM would open up.

Fourth, *Communications, Networks and Information Flows* were central to the performance of the role. The establishment of a network of REMs throughout the company (each with their own external networks and contacts) provided a base of information, knowledge and support that individual REMs could draw upon to help them diffuse ideas and expertise within their own regions. On the other hand, contact between REMs within the firm (and between REMs and engineers), although quite frequent, was rather irregular, informal and ad hoc and very much in response to specific queries. The geographical separation of sites, both from one another and from the regional offices still had a detrimental effect on the diffusion of knowledge because of the importance placed on social networks and contacts. There were also a number of other barriers to the flow of knowledge, expertise and advice. These stemmed from: contractual constraints; the lack of integration of separate information flows (e.g. 'quality alerts' for QA purposes operated as a quite separate system); and the lack of mechanisms for capturing learning from projects (post-project reviews were more like 'post mortems').

Fifth, with regard to *Technological Mechanisms*, email systems were clearly an important enabler of communication, especially between REMs, but also (potentially) between sites and regional offices and between sites themselves. However, there were a number of problems identified with regard to the use of the intranet and web-site within the firm. These included lack of standardisation of the system, practical difficulties in accessing the intranet and web-site from site, the lack of incentives to use and up-date information on the web-site and lack of resources to keep the web-site up to date and accurate.

Finally, the impact of *Objectives and Outputs* was significant. Clearly set out objectives for the role, although some were not so tangible and explicit, did provide a framework for assessing the role and for monitoring and appraising REM performance. However, while the emphasis on value engineering did mean the very direct application of engineering knowledge to immediate practical business problems, it also potentially inhibited aspects of the role that were related to the longer term accumulation and development of engineering knowledge.

COMPARISONS AND CONTRASTS ACROSS SECTORS

Although organisations in different sectors produce very different products and services, they can have similar organisational and project characteristics. Hence lessons from one sector on the process of KM may be relevant for another. What was clear from this study was that, despite sector diversity, the organisations experienced remarkably similar barriers and enablers in managing knowledge for project based learning. All the projects involved the development of new organisational products and/or processes. Perhaps as a result, the key enablers and barriers to KM were found to centre less on the capture of knowledge through ICTs and more on social processes and organisational factors. Critical enablers and barriers that cut across the projects are summarised below.

Project Characteristics

Existing research on project-based learning tends to focus on product innovation (Tidd, 1995). All of our projects, however (including the REM case), involved significant degrees of *process* innovation (even where the delivery of new services were part of the project, as in the pharmaceuticals and health cases). This process innovation posed unique problems for knowledge capture and transfer. Learning in product innovation projects tends to follow a convergent path - diverse sources of knowledge are progressively integrated within a single product or service specification. Learning can therefore be captured and transferred in explicit forms (e.g. as product design templates). In contrast what was learned in these process innovation projects was often tacit, intangible and context-dependent (e.g. changes in work practices, roles and responsibilities, attitudes and cultural values) and therefore difficult to capture in explicit forms, at least in ways that could be understood and applied in new contexts. Social and behavioural processes were therefore found to be more important than KM practices (e.g. the use of ICTs) aimed at the codification of knowledge (cf. Hansen et al., 1999).

Project Process Characteristics

A critical feature here was the development of a shared language and ideology centred around projects. Enforcing a standardised approach to the management of projects and a shared language allowed project lessons to be shared more widely. This enhanced 'absorptive capacity' – the ability to recognise the value of new knowledge, assimilate it with existing knowledge, and apply it to commercial ends (Cohen and Levinthal, 1990). However, the study also suggested that developing absorptive capacity for process innovation creates particular challenges: project learning capture depends as much on transferring elements of the context and social process which creates the learning outcomes as on transferring the outcomes themselves.

A number of key elements of the project process and context emerged across the cases that are illustrated by the construction case. Appropriate incentives and motivation to enhance people's willingness to share or exploit knowledge were important (Scarbrough and Carter, 2000; Keegan 1998). So too were adequate resources, training and education, management capability and appropriate skills and expertise (cf. Nonaka, 1994). The social process through which learning was generated highlighted a number of key elements. The development of shared languages/ideologies, as well as norms of knowledge sharing underpinned informal interactions (Ring and Van de Ven, 1994; Cole, 1999). The emergence of a committed project champion (Ginzberg and Abrahamson, 1991) was important in galvanising interest and celebrating success in complex and uncertain circumstances. 'Internal knowledge brokers' were important too in spanning boundaries between the project team and wider organisational constituencies.

Networking/Communication

This area is crucial in process innovation projects that, by definition, cut across existing processes and organisational routines. Each project team brings together a range of personal networks linking the project to the rest of the organisation and to information sources outside the organisation. The configuration and quality of these networks helps to influence the kinds of knowledge which the project team is able to draw on and the ability to transfer this knowledge to other groups. Our study confirms the importance of strong network ties for the sharing of tacit knowledge, and of non-redundant weak ties for accessing explicit knowledge in other parts of the organisation (cf. Hansen, 1999). At the same time, the value of personal networks also had to be balanced against the possible limiting effect of strong or redundant ties on information flows.

Learning Capture

While the development of product innovations is well recorded through various design iterations and artefacts, process innovation is less likely to leave such a trail and more likely to generate tacit or procedural knowledge. The role of IT and formal documentation in capturing learning was relatively constrained in our study. Learning capture was more dependent on: the identification of similar problems/opportunities that the project team's experiences could be applied to; the representation of that experiences as stories of success or failure; and the incorporation of learning into new process designs and routines which could be applied elsewhere.

Knowledge Transfer/ Outcomes

Knowledge transfer relates to the extent to which the outcomes of project learning are available to and applied by other project teams and the wider organisation. What became clear was that the tacit elements of project learning tend to be transferred as embodied knowledge (Blackler, 1995) through movements of personnel between project teams and through the importance attached to personal networks. Knowledge transfer also took place in our study via documentation and through electronic means (Intranet and email). However, the study suggested that IT systems may link geographically diverse teams but may inhibit knowledge transfer if it becomes a substitute for face-to-face interaction (Anderson, 2000).

Organisational Context

Many studies have highlighted the importance of the wider organisational context for the capture and dissemination of knowledge and learning (e.g. Kogut and Zander, 1992). Here the construction case study was the exception that proved the rule, in that it illustrated the benefits of a process improvement project within a single discipline (engineering). In other cases studied, multidisciplinary projects encountered problems of capturing and transferring learning across internal boundaries in bureaucratic contexts (cf. Adler and Cole, 1993). Other factors, however, were of importance too. In particular, the alignment between project objectives and strategic/financial control considerations was as important in other cases as it was in the REM case. Similarly, across the cases, the physical co-location or distribution of participants was seen as especially important in terms of knowledge transfer, since it affected the personal networks of individual team members and their interactions with other key participants (cf. Edelman, 2000).

CONCLUSION

This paper has attempted to explore knowledge management processes associated with project-based learning, by drawing upon a case study of such processes in a construction company and by comparing and contrasting them with comparable processes found in other sectors. The main finding to emerge is that processes of knowledge capture, transfer and learning in such circumstances rely very heavily upon social patterns, practices and processes in ways which emphasise the value and importance of adopting a community-based approach. These findings have wider implications for introducing new managerial initiatives in construction, in that they illustrate the difficulties, challenges and limitations of attempting to capture, codify and commodify project-based learning via the use of technological mechanisms (specifically, IT). They also illustrate the importance of trying to develop mechanisms that are able to capture the social nature and dynamics of knowledge management and learning processes.

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Innovative Contract Administration: A Report of the European Contract Administration Scan Tour

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ABSTRACT

This paper describes the findings and implementation of a European scanning review examining how European countries are employing innovative contract administration techniques that lead to more efficient delivery of highways. In a joint research effort between the US Federal Highway Administration (FHWA), the American Association of State Highway Transportation Officials (AASHTO) and the National Cooperative Highway Research Program (NCHRP), twelve representatives from Federal, State, private and academic sectors are scanning Europe to explore innovative contract administration methods. Specifically, the scan team is investigating six areas of interest; (1) Contracting Techniques, (2) Design-Build, (3) Alternative Financing (4) Concessions and (6) Performance Contracting. An in-depth literature and interview process resulted in the selection of Portugal, France, the United Kingdom and the Netherlands as the European countries with the most activity in these areas. This paper reports on the data gathered on the research tour and the implementation progress of the results in the United States.

INTRODUCTION

Traditional methods of contract administration have remained virtually unchanged in the U.S. public highway industry for more than 50 years. The traditional system of contract administration involves public funding of highway projects in a "pay-as-you-go" manner in combination with a two-step process of procurement that clearly separates design from construction. Design, for the most part, has been done by the public highway agencies and construction has been procured from the private sector in a low-bid approach. The traditional method is time consuming due to the linear nature of the design and construction process. The separation of design and construction, in conjunction with the low-bid environment, has often led to a culture of claims and substantial cost increases. While tested and familiar, the traditional method of construction administration in the U.S. highway industry is under increasing pressure to undergo changes to better meet our increasing infrastructure needs.

In the past 10-15 years, due to increasing traffic, deteriorating infrastructure and diminishing staff, public agencies have begun to employ a wider variety of contracting procedures. A change towards alternative contracting is occurring. The growing interest is evidenced by the number of participants in the FHWA Special Experimental Project - No. 14, the Federal Transit Authority's turnkey program, The American Road and Transportation Builder's Association (ARBTA) committees on public-private ventures, and lessons learned in the 1994 Contract Administration Techniques for Quality Enhancement Study Tour (CATQUEST), and the initiative of several state DOTs. However, even with the most generous estimates, only a very small percentage of current U.S. contracts fall into the alternative contracting category. Recognizing that European countries have significantly more experience in the use of alternative contracting procedures, a team of Federal, State, private sector and academic researchers was organized to observe and document those contract administration processes that might have value to the U.S. industry.

The American highway community has a high interest in improving contracting procedures and practices throughout the United States (US). Recent research indicates that European countries have at least ten years more experience using innovative contracting procedures. The experience gained by these countries offers the US valuable insight into the problems and solutions associated with using these innovative techniques. Recognizing the similarities and benefits that could result from an international examination of innovative contracting procedures, a diverse team of experts was assembled to research, document, and promote the implementation of best practices found in Europe that might benefit US practitioners. The Federal Highway Administration (FHWA) and the American Association of State and Highway Transportation Officials (AASHTO) jointly sponsored this study, under the National Cooperative Highway Research Program (NCHRP).

In June of 2001, a team comprised of Federal, State, contracting, legal, and academic representatives traveled to Europe to investigate and document innovative contract administration procedures that are employed in Europe to cope with growing transportation needs. The team traveled to Lisbon, Portugal; The Hague, Netherlands; Paris, France; and London, England. Additionally, the team met with Swedish transportation officials while in the Netherlands. The ministries of transportation, numerous private sector contractors, and research organizations involved in contract administration hosted the team.

In recent years, the European community has faced a multitude of problems that are similar to those that challenge the US transportation community today. The scan team discovered that European highway agencies appear to be better exploiting the efficiencies and resources that the private sector offers, through the use of innovative financing, alternative contracting techniques, design-build, concessions, performance contracting, and active asset management. European agencies have created contracts that focus on the users, while seeking to allocate risk appropriately and establish an atmosphere of trust in the implementation of procedures. The United States can directly and immediately employ many European procedures to help cope with its most urgent transportation needs.

FINDINGS

The scanning team organized the findings into six sections for presentation and implementation. Although there are some overlapping concepts within sections, the team decided on this format to elevate the topics that appeared to have the most potential for impact.

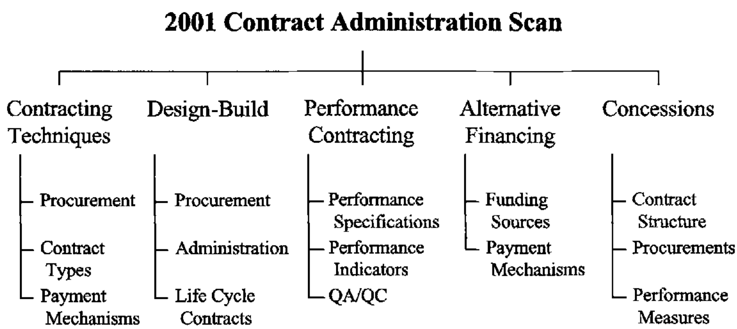

Figure 3.1 Organization of Scan Findings

CONTRACTING TECHNIQUES

European transportation agencies are implementing a wide variety of alternative contracting techniques that could have a tremendous impact on the efficiency and effectiveness of contract administration in the United States. Similar to the US relationship between FHWA and the State DOTs, the EU directives establish minimum requirements that must be used by its members for procurement, but individual countries can develop unique contracting techniques that fit distinctive needs.

The most notable difference between European and US procurement methods is that *best-value* awards are widely used in all types of procurements. Low-bid selection, although still used, is becoming less common. The Europeans have found that best-value selection, utilizing transparent and uniform processes, enhances competition and innovation. In the case of long-term maintenance contract procurements, the business culture and quality were weighted much more significantly than the price and technical portions of the procurement. Short listing is widely used to ensure that all potential proposers are competent technically and meet the owner's other minimum requirements. In cases of public-private ventures and privatization, careful consideration is given to the economic benefits of the procurement. The public sector transportation agencies have dedicated significant effort to evaluating and assessing best-value proposals, and, in some cases, have significantly changed their organizational structures. Finally, the ministries of transportation visited on the scan utilized confidential discussions in their procurement processes much more readily than in the United States. The European agencies provided examples of an increase in design and construction innovation due to these discussions in the procurement phase.

The United States is currently employing a number of similar techniques, but the scan revealed new techniques that have merit for consideration in the States. Some of the contract types discussed in this report appear in the table below. Figure 3.1.1 also illustrates the relationships amongst parties in the contracts.

Contracts Similar to U.S. Methods	Contracts not Currently Used by U.S. Agencies
Design-Build	Framework Contracts
Design-Build-Maintain	Management Agency Contracting (MAC)
Design-Build-Operate-Maintain	Private Finance MAC
Concessions	Integrated Supply Chain Management

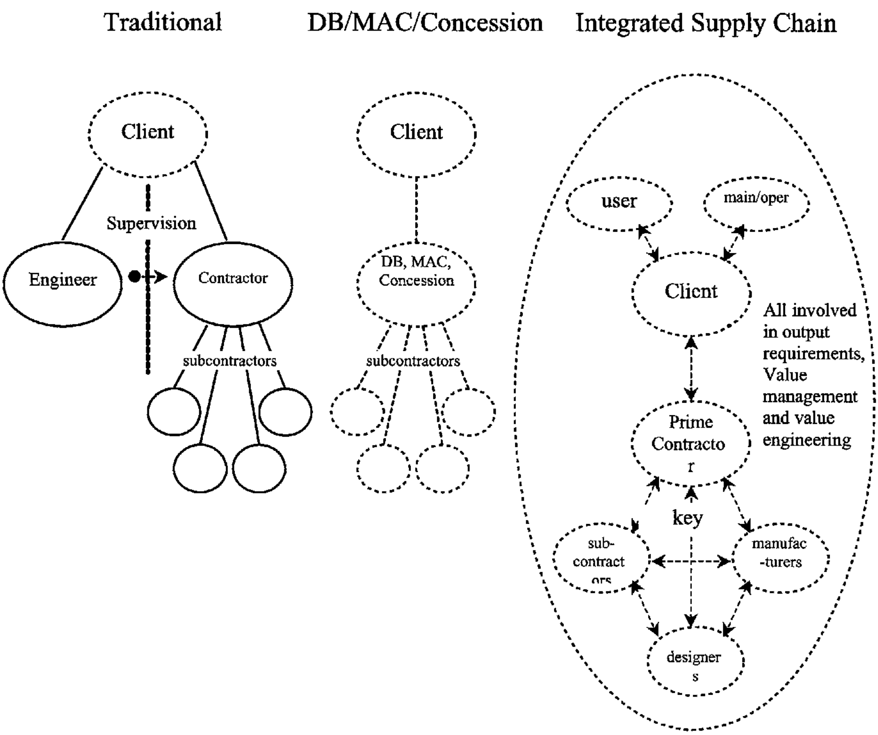

Figure 3.1.1 Traditional, Single Source and Integrated Supply Chain Contract Models

In summary, all of these types of contracts promote creation of partnerships between the public and private sectors. European agencies are actively working towards development of relationships with the private sector based on trust and delegation of responsibility.

Certain alternative procurement methods and contracts can combine non-traditional payment mechanisms to optimize their benefits. In many cases, payments are not based on units of work completed, but rather on availability of the product at the end of the project. The private sector providers are required to finance the cash flow during and after construction. They ultimately receive payments based on factors such as availability (i.e., number of lanes open), quality of performance (i.e., smoothness), and/or safety (a reduction in the number of crashes, measured against a baseline). Disincentives were observed on maintenance contracts, and incentives were readily used for safety.

DESIGN-BUILD

In the countries visited, design-build was observed to be the contracting method of choice for many types of projects, ranging from green-field construction to pure maintenance contracts. Design-build is also an inherent component in concessions and public private partnerships. In the UK, the Highways Agency's contracting method of choice is design-build. Design-build contracts are typically awarded on a best-value basis. In the best-value analysis, lifecycle costs are analyzed using net present value (NPV). In the UK, the Highways Agency indicated that in the early 1990s they carried preliminary designs too far, prior to tendering. They have now corrected that error. One area where the Europeans appear to be more advanced than the Americans is in writing *outcome (value) specifications.* US practitioners are struggling with similar performance specifications. In Europe, the issue of quality assurance in design-build contracts is primarily dealt with through the use of 5 to 10 year warranties and 30-year concessions. The use of alternative financing, operation, and maintenance, in conjunction with design-build contracts, minimizes the need for owners to perform time-consuming and redundant inspection and testing. The lessons learned on this scan tour include the types of projects suitable for design-build, the use of best-value selection for design-build projects, the need to minimize the level of design in the solicitation, design and construction administration, third party risks, the use of warranties, and the addition of maintenance and operation to the design-build contracts. In summary, the design-build techniques observed in Europe promote a level of partnering and early contractor involvement not yet widely seen in the United States.

PERFORMANCE CONTRACTING

Performance contracting is in its infancy in the U.S. transportation sector, but the tools and techniques are well established in Europe. Performance contracting allows the contractor to employ whatever means it determines are most appropriate (and economical) to satisfy the performance specifications provided by the owner. Performance contracts allow innovation through creative design and construction methods – and are thought to lower the overall price of a given project. Performance contracts necessitate alternative procurement practices with past performance and innovative solutions as major factors in the selection process. Such contracts are also ideal candidates for alternative payment mechanisms, typically utilizing end product qualities as measurements.

Performance specifications are critical elements of performance contracting. In the Netherlands, the highways agency has extensive experience with drafting performance specifications. The Dutch are testing a series of 60 pilot projects to measure performance contracting versus traditional prescriptive methods. They define performance specifications in five levels of requirements that range from road user wishes to requirements for basic materials and processing. Performance specifications detail both the operating level and minimum condition of the facility at the time it is returned to public ownership.

An item of concern in performance contracting in the United States is QA/QC (quality assurance/quality control). Traditional QA/QC roles and responsibilities in the U.S. can impede the effectiveness of performance contracting. Performance contracts observed in the scan placed the responsibility for QC solely with the contractor, and the owner retained only a minimal QA role. Owner QA is built into the process at various "stop" or "control" points on projects. There are also unique processes for penalty points and quality audits in lieu of heavy owner inspection. In one instance, the owner gives the contractor yellow or red cards for quality violations, like a referee in a soccer game. One yellow card is a warning and allows the contractor to correct work while improving its process or fixing the problem. Two yellow cards, or one red card, mean that the contractor must stop work until the violation is remedied.

ALTERNATIVE FINANCING

Many of the alternative financing techniques in use in Europe have the potential to be used in the United States. However, two significant differences between the U.S. and European finance processes must be considered. First, the countries visited on the scan do not have tax revenue sources dedicated exclusively to transportation needs. This means that gasoline taxes and the like are not earmarked for transportation projects, but are deposited into a general fund with other taxes.

The general funds provide money for a variety of needs, including transportation projects, but no taxes are specifically dedicated for future transportation projects. The second difference is that European governments do not have the ability to use tax exempt financing for public transportation projects, as is the case in the United States. Although this means that interest rates are higher for European projects, it also means that such projects are not subject to the management contracting rules applicable to U.S. projects using tax-exempt financing, and makes private financing much more competitive with public financing. For example, in the United Kingdom (UK), the interest differential between backed by publicly guaranteed funds and private funds is sometimes less than 1 percent.

Alternative funding sources in Europe include a combination of bond and bank financing. Private financing is used much more readily than in the United States. In some cases, this is due to the fact that governments have reached ceilings for public debt; in others it is simply the result of the fact that private financing is a competitive solution. For example, the Dutch created a toll tunnel project through a limited liability entity and plan to transfer ownership to the private sector by selling shares of the entity to the public when the tunnel is operating profitably. In Portugal, concessionaires bid for the rights to maintain and operate existing highways, creating a type of off balance sheet approach to government funding and even purchase highway infrastructure.

The scan revealed several alternative financing payment mechanisms. As in the United States, real tolls are in use, but, in some situations, real tolls meet with public and political resistance. Both Portugal and the UK are experimenting with systems of "shadow tolling". Shadow tolls involve payment of user fees by the government based on the number of vehicles that use the facility, allowing the concessionaire to obtain financing for the project secured by the user fees and based on traffic studies. The user fees are paid on the basis of traditional sampling methods and high tech count mechanisms establishing the number of vehicles using the facility. This arrangement gives the concessionaire the risk of, and reward for, the number of vehicles using the road. In the UK, shadow toll arrangements are evolving from a "toll per vehicle" scheme to a payment based on highway performance and availability. Finally, in all countries, the team found examples of the temporary transfer of existing government assets and revenue sources to the private sector. Transfers appeared in a variety of methods, from maintenance to tolls, for durations of up to 35 years.

CONCESSIONS

While only a minimal number of quasi-public concession and private transportation projects have been developed in the United States, the European countries visited on the scan are leveraging concessions for major portions of their highway systems. Portugal, for example, has gone from 431 km of concessions, in 1991, to a planned 2700 km of concessions in 2006 – representing 90 percent of its national highway network. The concession system is allowing Portugal to complete its strategic National Road Plan by 2006, an 8-year acceleration over the projected timeline use of traditional methods. Concessions are used for both construction and maintenance of European motorways. Concession periods vary, but were commonly found to be 30 years. The Dutch are promoting concession periods that equal 75 percent of the design life of the product. Both public agencies and concession companies commonly obtain long-term warranties from their contractors, but the team observed widespread use of maintenance contracts in lieu of warranties. A variety of concession structures were observed, ranging from fully private to quasi-public, and fully public entities, with varying requirements for private sector equity. The study found use of a *"Public-Private Comparator"* employed by both the Netherlands and the UK in making procurement decisions. Drivers for the use of concessions range from lack of public funding to a belief that private financing and maintenance delivers a higher quality product and provides benchmarks for public sector performance.

CONCLUSIONS AND RECOMMENDATIONS

The U.S. highways agencies should better utilize the efficiencies and resources that the private sector has to offer, through the use of alternative contracting techniques, design-build, innovative financing, concessions, and performance contracting. Agencies must focus on the users while equitably allocating risk and seeking to establish an atmosphere of trust in the implementation of procedures. This finding of this study present a number of tools to assist U.S. agencies in meeting their growing infrastructure needs. A documentation of knowledge and best practices learned on the European contract administration scan is provided in an effort to implement these tools and make the U.S. transportation system more efficient and effective for the public.

The 2001 Contract Administration Scan Team was privileged to be able to travel to Europe and visit with the representatives of five host countries (France, The Netherlands, Portugal, Sweden and the United Kingdom). The team witnessed many alternative contract administration practices and unanimously believes that a number of these can be immediately applied in the U.S.

Following the European tour, the scan study moved into the Scanning Technology Implementation Phase (STIP). All team members are actively implementing practices that are applicable to their positions in the transportation industry, but a smaller STIP team was created to move the implementation forward quickly. The STIP team met to determine the most appropriate concepts for implementation from the numerous innovations and best practices discovered on the scan.

The STIP team developed a questionnaire containing the top thirteen concepts found on the scan, which promised the most potential to impact the US highways industry. All of the scan team members then responded to the questionnaire. The entire scan team rated the implementation options for on a scale from "5 – Extremely Important" (idea or recommendation is very critical and will significantly improve contract administration procedures or project delivery methods) to "1 – Not Important" (idea or recommendation will not significantly improve current practices or solve any real problem). The table below provides the ranking for the implementation items.

Rank	Category	Implementation Concept Description
1	Contracting Techniques	Best Value Procurement Techniques
2	Contracting Techniques	Procurement Utilizing Confidential Negotiation Processes
3	Performance Contracting	Performance Specifications
4	Performance Contracting	Long-Term Maintenance Contracts
5	Performance Contracting	Quality Control is Sole Responsibility of Contractor (penalty card quality systems, etc.)
6	Design-Build	Life Cycle Cost Award
7	Alternative Financing	Opportunities for Joint Development
8	Contracting Techniques	Alternative Payment Mechanisms (user based payment mechanisms, e.g. product availability, milestone pay points, contractor determines pay quantity, etc.)
9	Concessions	Performance Metrics for Concessionaire Selection and Payment
10	Contracting Techniques	Alternative Contract Types (framework, managing agency contracting, integrated supply chain management, etc.)
11	Concessions	Integrating Concessions into Long-Term Planning
12	Alternative Financing	Use of Shadow Tolls (either based upon use or performance)
13	Asset Management	Valuation of Assets

All thirteen of the implementation concepts are important, but the top three were determined to be the focus for implementation due to their high impact of and relative ease of implementation. These three techniques, and six of the top eight, are found in the contracting techniques and performance contracting categories. These three concepts are presented as primary findings below. The other concepts are summarized as additional findings in the order that they are found in the report.

PRIMARY RECOMMENDATIONS

The U.S. has much to learn from European highways agencies. In particular, the best-value approach combined with the ability to negotiate technical terms and alternative concepts with selected contractors has enabled agencies to award contracts at reasonable cost to those providers with a proven track record for responsiveness to the public sector's needs. The U.S. Federal Highway Administration and the State DOTs should consider more use of best-value negotiated contracts, giving contractors the opportunity to develop reputations that enable them to be exceptional performers and compete in best-value procurements. The U.S. Federal Highway Administration and the DOTs should also consider moving towards the use of more performance specifications, which will allow the private sector industry to innovate and continuously improve the quality, efficiency and safety of the highway system. These performance specifications will require associated performance indicators to measure and benchmark exceptional performance. Specifically, the scan team recommends that the following concepts and tools be explored in the U.S. as a means to speed the delivery of our infrastructure and increase the quality of construction and maintenance.

Use best-value award techniques in the selection wherever it is shown that value can be added through quality or innovation.

Explore techniques to fairly and equitably employ confidential negotiations and discussions of alternative proposals to capitalize on the creativity and innovation of the private sector.

Create consistent performance specifications that define the owner's performance objectives, which can be used to promote consistency in specifications while allowing for innovation in design, construction and maintenance.

In conjunction with the performance specification system, develop consistent and objective performance indicators that allow for the measurement and verifiable benchmarking of the performance specifications. These performance indicators should be used to create a system of continuous improvement for the industry.

Explore the formation of an audit group, similar to the UK. Project Review and Performance (PRIDe) group, as a means to benchmark performance indicators for use by all states. This team will be able to ensure, through diligent benchmarking, that projects are being delivered at competitive costs in lieu ensuring competitive costs through our current low-bid system.

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Creating High Performance Office Environment By Using (Development) Partnering Procedure

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ABSTRACT

This paper presents some new methods to operate in fast and complex processes. Changes in the business activities of companies, especially in the high-tech field, are very rapid today. This presents great challenges to managing building process including briefing, designing and implementation process and to meeting the space needs of companies. Clients are unable to tell beforehand what type of spaces they want since the changes in business activity are often extremely fast. It is not always clear who his going to occupy the spaces to be designed, or the user may even change during construction due to rapid developments. Thus, the first alterations may have to be done already as the initial user moves onto the premises. This requires flexible space solutions, design processes, realization of buildings spaces and rental terms. Rapid changes in business also enforce for faster lead times in process.

Large development contribution by few partners working with Tampere Technology Center have been powered to create new ways to operate. This paper describes some successful results which have been realized.

INTRODUCTION

Changes in the business activities of companies, especially in the high-tech field, are very rapid today. This presents great challenges to meeting the space needs of companies. The space requirements of clients in a technology center environment such as Hermia vary a lot: from a single room of 6 m^2 to large units of 10,000 to 20,000 m^2.

Clients are unable to tell beforehand what type of space they want since the changes in business activity are often extremely fast. It is not always clear who his going to occupy the spaces to be designed, or the user may even change during construction due to rapid developments. Thus, the first alterations may have to be done already as the initial user moves onto the premises. This requires flexible spaces and rental terms.

The goal of the research was to create a customized space concept for Hermia's operating environment. Specific goals were set for the space concept and its content. It is to

- include alternative solutions for the design and implementation of spaces
- be of reasonable cost, open and flexible
- support construction of both office and production facilities
- include alternative solutions for flexible rental of produced spaces and services
- take into account the life cycle economics of the building
- promote the growth potential of companies in the building and/or the Hermia center
- assist in procuring financing for new building projects.

New space concepts are intended to provide firms an environment and support services that improve their competitiveness and allow quick changes in spatial arrangements.

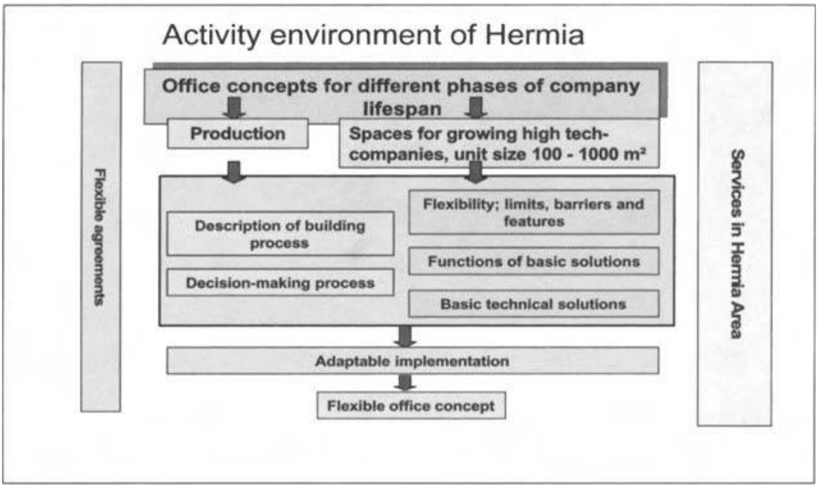

Figure. 1. Focus areas of development project and the affiliation to the business idea of Technology Center.

Implementation of development project

The research project was carried out as a company project under Tampere Technology Center. One financier of the project has been the ProBuild Technology Program of the National Technology Agency (TEKES). Other financiers and project participants are presented in Fig. 2—as are the work groups into which the project has been organized, and where most of the work has been done. All parties could freely participate in the work of all other work groups.

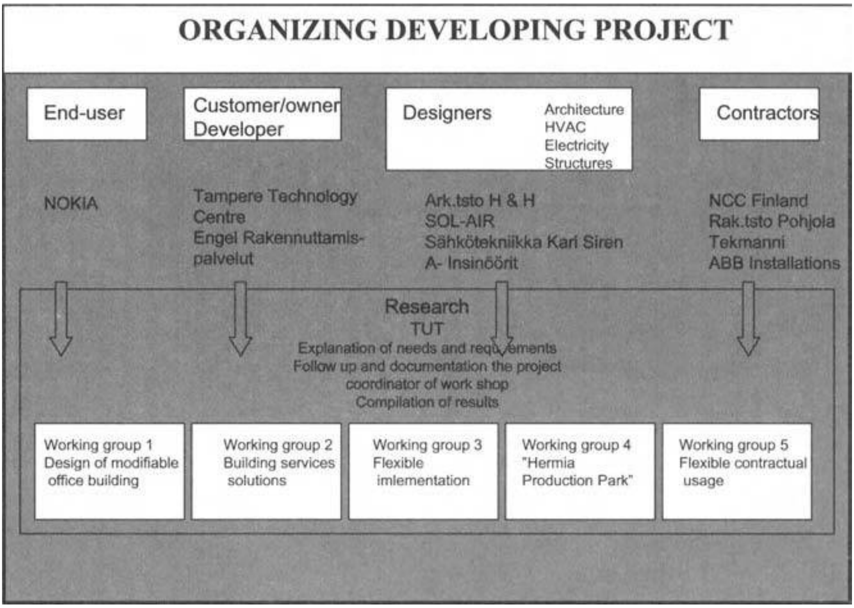

Figure. 2. Parties to development project and its organization.

Process description of a business-premises project

Since the future client companies, i.e. users, are generally not known at the beginning of the process, the spatial solutions must be designed to be as open and flexible as possible. This requires a flexible design process and, especially, cooperation between specialist designers. In order to achieve flexibility and have any chance of success, the entire project organization must be characterized by openness and trust.

When the end users are not yet known, the development of a business-premises project does not move quite as usually. The process requires more resources, for instance, in defining the business idea of the building, alternative courses of action and users' needs. Consequently, the project programming phase is the most important phase from the viewpoint of the end result, and it pays to take time to review various solutions.

The different phases of the process overlap, and the stages of traditional project progression are not necessarily discernible. Yet, it is important to set certain milestones such as documentation of the project plan in a clear fashion in order to record design goals and instructions. Special attention is given to the decision-making process at the development and design phase of the project (decision-making schedule) which has a significant impact of the progression of the project and its final outcome. As regards the decision-making process, it is important that the entire team with its input of expertise participates in it, so that decisions which have a major impact on the end result are not made solely by the client.

A modifiable office building

The concept of modifiability embraces flexibility and the implied changeability. Flexibility can be considered a general concept which refers to the different modes of realizing the multiple uses of a space.

Modifiability allows changing an implemented solution later with very little dismantling and installation at a low cost. The architect and the structural and building services engineers are to make joint design solutions which allow easy-to-implement and low-cost spatial changes and arrangements.

Here, a modifiable office building refers to one which meets the needs and requirements of users, companies and investors to the highest degree possible. This means that the building and its systems cannot be designed to serve just a single, or the first, user organization, but design must strive to factor in probable changes in operations and spatial arrangements. For cost reasons, design has to be based on some assumptions and limitations as to which activities and changes the building must adapt to. Often, the needs of future users must also be envisioned.

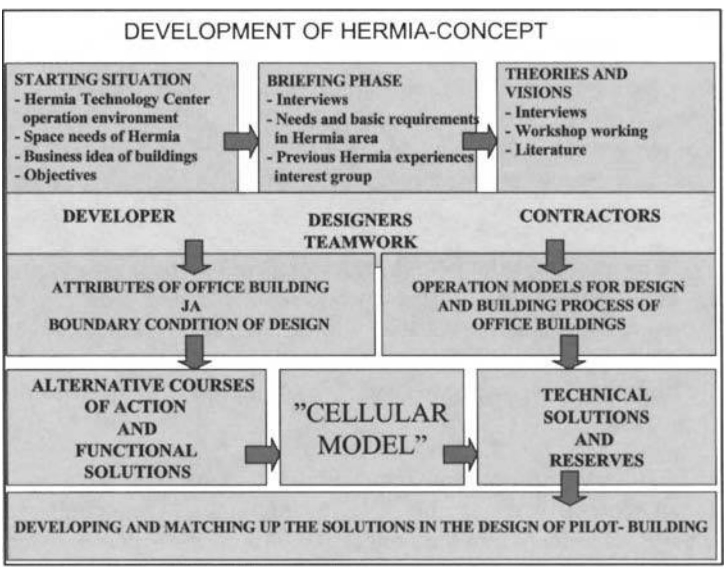

Figure. 3. Formation of Hermia business-premises concept.

The definition of the bases of design already decides the modifiability characteristics of a building to a high degree. In order to keep costs in check, it is necessary to set clear goals for modifiability in that connection. The problem is to determine what types of situations to prepare for with regard to the building. We should be able to give designers such input about these situations that they can come up with solutions that adapt to changes. Clear limit values for various levels of modifiability are required to facilitate decision making. Decisions on allowances to be made influence directly the costs, future yields and life cycle costs of the project. Yet, everything in a building cannot be modifiable. Modifiability should not be carried too far. Instead, optimal combinations of various properties, the possibilities and value added they create, and resulting costs should be pursued.

The right decisions and controlled design management according to set goals ensure that built spaces offer future users as many alternatives with regard to spatial arrangements and occupancies as possible. The problems posed by the design process of a multiple-user building are a challenge and place demands on the design team and the decision-making process.

Model development

The development of the business-premises solution has taken into account the business structure of the technology center environment and the core competence of client companies by studying their spaces and the activity therein, the demands on office buildings by various interested parties (users and investors/owners), and visions about future development trends in office work and business-premises construction. The operating environment at Hermia sets certain requirements for business-premises construction due to

- constant shortage of parking spaces
- rapid growth of firms, and quick changes in space needs
- high demand for different types of spaces; problems of multiple-user buildings
- increasing quality standards
- improvement and maintenance of high-tech image.

Modifiability and a sufficient level of technical systems as well as flexibility vis-à-vis future demands of growing high-tech companies were set as the main goals of the solution to be developed.

Internal feasibility studies at Hermia resulted in setting as the primary boundary condition for modifiability of rental spaces that they are divisible into units of 200 m^2 when the gross floor area is about 1,000 m^2. Divisibility was naturally also made a boundary condition for specialist designers. Moreover, design was to minimize the changes in spaces required during the life cycle. One starting point was also that the solution provide users meeting places, and that it can be relatively easily replicated in later construction.

Operational model of building

A starting point of the development of the model has been to make most of the traffic inside the building flow through a single node. This creates so-called meeting places within the building such as a restaurant or a market square-type space. Other necessary services such as information, consulting and commercial space can be built next to such a meeting place as desired.

The development culminated in the idea of a so-called cellular model developed by an architectural firm where the building is composed of four blocks that are joined together. The blocks are connected to a single solid element, for instance, a stair well, a lift shaft or building services ducts. In such a solution, the entity (building) is made up of flexible zones (Fig. 4) where the modifiability of spaces increases from the core (center) of the building outwards. The zone concept also takes into account the functional needs of spaces and the demands of different spaces on building services (especially ventilation and air conditioning).

Traffic zone

There is a solid element in the center of the building where all vertical traffic occurs. It includes the stair well, lifts and vertical ducts for building services.

Installation zone

By positioning ducts on the outer perimeter of the stationary core, sanitary and kitchen facilities can be made to join the ducts directly. These spaces are also modifiable; sanitary facilities can be built to meet the user's needs whereby an unnecessary toilet/shower room can be turned, for instance, into storage space. The spaces are, however, ready for pipe connections.

Conference zone

This zone has spaces where a larger number of people can assemble at a time, such as conference rooms, lounge areas, group work rooms and, sometimes, even small-scale laboratories.

Workspace zone

Spaces intended for normal office work functions where office rooms, open-plan offices or a combination of these can be formed.

On the other hand, the solution allows dividing the building into functional zones with nearly the same boundaries as the flexible zones:

The client zone, and *the service and maintenance zone* within it, are spaces through which all client and maintenance traffic flows.

The conference zone at the interface of the client zone and workspace zone serves as something of an internal meeting place/area. In a sense, the zone separates the traffic and service areas from the regular working space.

The workspace zone can be realized, if necessary, so that only the user firm's staff have access to it. The zone can comprise office rooms, open-plan offices or combinations of them.

The expansion zone

If necessary, the frame and facade structures can be designed so that expansion of the building is possible, the construction site allowing.

The floor area of about 1,200 m^2 of the pilot project turned out quite optimal for implementing the theoretical model in question. Any major enlargement of the base of the building beyond that necessitates another so-called solid element with lifts and services ducts. Up to six stories can be built without problems with the model. If more stories are added, an extra "building services floor " is required.

In planning the activities in the building, the need of services also has to be considered. The ground floor can house services for the building or the entire center such as restaurants, commercial space or office services as well as regular office space. The floor has, for instance, conference and educational space. The building's entrances are positioned so that all traffic is directed to the possible reception or information desk.

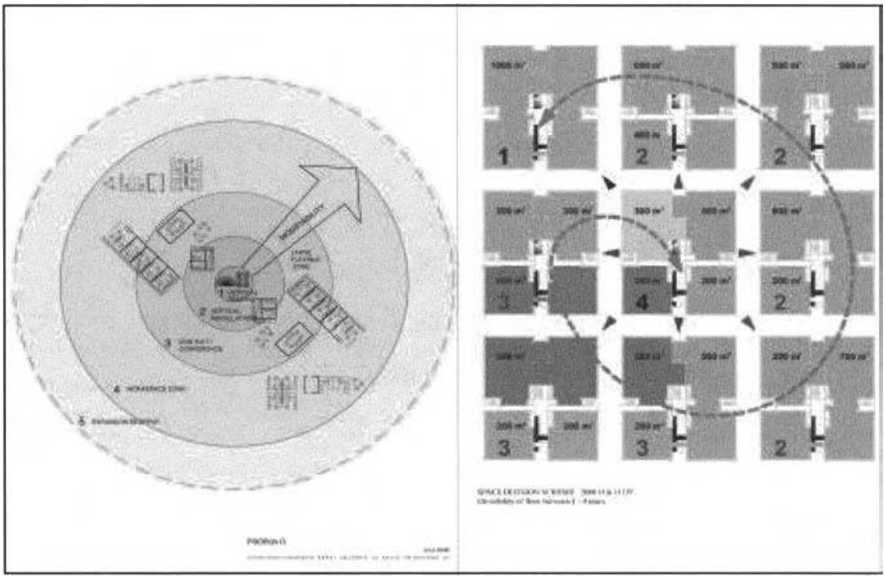

Figure. 4. On the left has shown the flexible zones of multiple-user building; modifiability increases with distance from the solid core. On the right has shown divisibility of floor of zone-thinking-based pilot building between 1-4 users (200-1,000 m^2).

Basic building services solutions

The solutions make allowance for modifiability and meet all existing basic criteria. The HVAC systems are dimensioned for extra capacity needs, and the main ducts and pipes are dimensioned generously. There are four vertical HVAC shafts which ensures short and problem-free installations on floors. Symmetrical positioning of shafts around the solid core of the building has created almost optimal routing of HVAC ducts and electrical cabling. An effort has been made to take into account changes in the occupancy of spaces when deciding on HVAC and electrical solutions. Ducts and machine capacities are dimensioned to enable additional building of various types of spaces (laboratories, etc.). The contents of ducts as such as modifiable, and the intention is to make them accessible from the side of common spaces.

Besides modifiability, possible expansion of the building can also be taken into account in the design of building services by

- dimensioning a large enough service water pipe

- dimensioning large enough surface drainage connections for the site, by laying pipes at sufficient depth, and by avoiding building underneath the expansion

- dimensioning district heating service connection that can also supply the expansion

- equipping the heat distribution room with connections for hot domestic water, heat exchangers and piping for future expansions.

Some details of the solutions for the pilot building are provided below:

In general: machinery, pipings, air conditioning equipment, etc. are generously dimensioned with about 30 % excess capacity.

Water supply and drainage systems

Personnel facilities, kitchens and other water-consuming spaces are positioned in the central area of the building where modifications are easiest to perform. The above-mentioned spaces can be taken into use immediately, or as new users move in, since drain pipes have been laid up to the spaces and water points are close by. Water mains are generously dimensioned allowing large variation at consumption points.

Heating

The radiator heating output of the building hardly changes, even if the spaces are put to new use. Each floor is equipped with short radiators which allows installing or removing partitions according to the 1,350 mm modular arrangement without altering the network. Heating risers are situated in corners where no need for alteration exists.

Ventilation

Floor-specific supply air, extract air and heat recovery systems. Generous dimensioning of equipment and ductwork means in practice that

- the air flow in ducts can be changed by 30-130 % on each floor

- the number of building occupants can be increased by about 125

- the spaces of an entire floor can be turned into so-called laboratory space, if desired
- modifiability of ventilation is 2 $l/s/m^2$ – 4 $l/s/m^2$

Partitions of each floor can be moved freely according to the modular arrangement. If necessary, supply and extract air valves and the related terminal ductwork can be increased or reduced very flexibly as the pressure-controlled regulation system always maintains the balance of ventilation networks, and they need no separate regulation as air flows vary.

Air conditioning

The building is equipped with a pump-operated water cooling system. Cooling water is used to cool the supply air of air conditioners and the supply air box-beams or cooling apparatus. Placement of the cooling box-beams adheres to the modular arrangement so that changes in the location of partitions do not cause changes in the box-beam network. The temperature of spaces is regulated by temperature detectors and adjustment units which allow altering the temperature of a space. In cooling, modifiability means that the cooling capacity of a floor can be increased up to about 200 W/m^2 from the basic level of 60 W/m^2.

HVAC and electrical routings—the systematics of positioning the spaces and routings required by technical systems—have been designed with the installability and modifiability of the systems in mind.

Electrical engineering

Basic principles of electrical engineering:

- modifiable main electricity distribution system
- quickly installable and modifiable distribution board of office space
- modifiable system for measuring energy consumption
- modifiable office electrification system (Enstonet product family)
- modifiable general cabling system.

The above electrical systems for offices are based on a modular product family whose components are nearly 100 percent modifiable and reusable by the users themselves. Wiring with push-pull couplings runs mainly in the ceiling supported on cable trays and is brought down at work stations to meet the needs of the user (e.g. inside columns, as retractable fixtures in conference rooms or as pendant fixtures). No cabling is laid in partitions intended for modification.

Lighting

In office space it is possible to choose between direct or indirect lighting according to users' needs. Most prefer indirect lighting which may consist of pendant or recessed lamps in the case of suspended ceilings. Lighting control options are pull cord, wall switch in open-plan offices, or automation which uses the sensors of the HVAC automation.

Structures

When designing the building, only the frame and foundations are set the requirement that they must endure for the life of the entire building which is generally from a few decades to a hundred—even several hundred—years.

Vertical bearing frames

An essential factor determining the modifiability of a vertical bearing frame is its type; a column frame is the most flexible and allows later spatial alterations. The solid wall frame generally used in housing construction is the least flexible. Especially in urban centers spaces may have to be modified for office or commercial use. Then, the wall frame, which is difficult to modify, may prevent change of occupancy.

Dimensioning and properties of intermediate floors

The intermediate floors in office buildings are generally dimensioned for a human load of 2.5 kN/m^2. The recommended human load from the viewpoint of modifiability should be 4.0 kN/m^2 everywhere since it allows later location of crowded spaces as desired. The hollow-core slab allows long spans and a vertical frame of columns which improves modifiability.

The possibility of making openings later should also be considered when designing intermediate floors; for instance, to install extra stairways or to expand ductwork. The hollow-core slab may be the most difficult in this sense since all but the smallest openings require bearing vertical structures beside them.

Floor height vs. clear height

Floor height minus the overall thickness of the intermediate floor must be sufficient to allow installation of present and future building services while maintaining reasonable clear floor height. Beam sections that extend below the floor slab are highly likely to be an impediment to later changes to building services. A floor slab of uniform thickness is the most flexible from the viewpoint of future changes.

Beams underneath the slab increase floor height. For instance, low L-beams lie 100–200 mm below the slab. They cannot be perforated, and therefore building services installations are carried under the slab.

Building services installations generally require a vertical clearance of 400–700 mm which results in a floor height of 3,200–4,000 mm depending on the spatial and HVAC solutions of offices.

Expandability—Facades

The expandability of a building as well as the possibilities of erecting other buildings on the site should be determined in the early phase of the project. For instance, in the case of industrial facilities, the need may arise later to build new space next to the facilities to be built now. Therefore, preparations should be made for expansion when designing the positioning and loading of foundations, columns, beams, and possibly slabs as well as the easy removability of partitions. If the town plan allows extra floors to be built, the later utilizability of this option must also be ensured.

Flexible implementation

The following goals have been set for the implementation concept from the standpoint of Hermia:

- The implementation plan must serve both the client and the contractors.
- The “Hermia implementation team” is engaged in constant development in the background disassociated from actual projects. The development may be development of processes, design solutions, etc.
- Projects should be launched and carried through very quickly.

- Procurement methods should support flexibility aims of projects, that is, changes in buildings should be feasible as long into the construction phase as possible.

The so-called partnering model which uses as examples models referred to in literature as **strategic partnering** and **development partnering** have been developed and tested during the project. In the development-partnering model a professional client creates a network of cooperation. All parties as a team develop their processes and solutions for an office building also outside actual building projects. Thus, the model is based on development projects carried out before the building projects where project-independent design and preparations for procurement are done. Technical preliminary design which resorts to standardization and modular solutions focuses on internal structures and building services. When the decision to launch a project has been taken, the building project is launched quickly through procurements and prefabrication.

In the presented models partnerships of very long duration are generally established. Long-term partnering can create certain additional advantages such as

- joint operations/services
- learning from recurring processes (projects)
- better mutual understanding between partners.

A difference compared to many traditional implementation models is that contractors are also involved in the early phase of the construction project (development and turnkey projects excluded). In an actual project this means that some process phases can be realized in advance, for instance, determination of spatial requirements, selection of technical solutions and drawing up of procurement and team contracts. This speeds up the entire project process. A major factor expediting the project is the exclusion of the competitive bidding phase whereby design resources need not be "wasted" on preparing tender documents. Other benefits are also gained: designers' designs are immediately implementable since contractors have participated in their development, feedback from earlier projects is readily available for the team, processes become more effective and people learn more as projects of similar type are repeated which cuts costs.

In the case of Hermia, development partnering means that the "implementing team" carries on continuous mutual development activity. The team meets regularly to ponder

- how to implement subsequent projects

- what was done wrong in previous projects
- which new solutions and lines of action can be used in new projects
- etc.

In addition to the above advantages, continuous development also improves the smoothness of project implementation and its overall quality in the following ways:

- There is just one implementation team which knows the operating environment and other members' modes of behavior as well as thought-out, agreed contractual usage and operational models, which results in
- fewer disputes
- savings in time and costs due to dispute settlements
- used solutions are either proven or jointly developed and selected by common decisions
- processes develop and become smoother
- costs are reduced
- feedback from earlier projects can be utilized effectively and past mistakes are not repeated
- improved quality and safety
- shorter design and construction time and assured completion
- more constant job-order bookings and income
- better working environment.

SUMMARY

Present trends in business-premises construction present new challenges to the design and construction processes of buildings. Real estate business and related services have introduced new aspects to building design which must increasingly be considered in the processes. Modifiability, consideration of life cycle costs, and

the service level expected of a property are factors which have the greatest influence on the performance and technical properties of business premises and the resulting costs. For the end result, it is important that the desired levels of the above-mentioned properties are established at the goal-setting phase, and that support for related decision making is also received from experts of the fields in question. The following is a short list of trends affecting business-premises construction:

- User is no longer the owner
  - real estate business
  - need of services
  - outsourcing of activities
- Increasing demands of users and owners
  - more properties
  - more operational alternatives
    - changes in work modes and space utilization solutions
  - life cycle requirements
  - technological development
  - cost-effectiveness
  - flexibility of both spaces and technology
- Multiple-user buildings and related problems

  Clients are unable to tell beforehand what type of space they want:
  - fast changes in business of companies
  - companies outgrow their facilities
- Increased building services
  - investments for the future and their profitability

- Flexible implementation of projects from the viewpoint of all interest groups.

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How to SMARTWaste™ the Construction Industry

James W. Hurley, Senior Consultant, BRE

INTRODUCTION

It strikes me as an exciting time when considering the sustainable construction, demolition and refurbishment of our towns, villages and cities. It encourages me too that we all have a vital role to play in achieving a balance between social, economic and environmental needs that dictate local, regional and strategic development plans.

In terms of sustainable development, the European construction industry is at a turning point with regard to materials waste minimisation and management. Simultaneously, the waste management industry has been set a challenge to reduce dependence on landfill and offer materials recovery services and recycling facilities. In the medium to long term stakeholders such as clients, contractors, planners and manufacturers will play their part in achieving a more sustainable approach by extending the life cycle of materials, products and resources. Similarly, to reuse and recycle recovered products and materials into high- rather than low-grade applications.

In order to take these steps it is important to benchmark and categorise our waste streams so that we can plan and invest wisely, efficiently and practicably. There is some foundation in a commonly held view that "in order to manage something you must first of all measure it". The BRE web-based tool, SMARTWaste™ and its simpler counterpart SMARTStart, has been specifically developed to meet this goal and to provide a wealth of interactive information and reporting features. These include the source, type, quantity, cause, cost, wastage rate and trend of the overall waste, individual waste groups or key waste products in order to establish material waste management strategies that are monitored using environmental performance indicators and action plans. This wholesome tool, under continual development, is expected to set a precedence for material waste auditing in many sectors and locations.

MATERIAL WASTE IN THE UK CONSTRUCTION INDUSTRY

UK Construction & demolition Waste

Waste in the European Construction Industry

It is estimated that the United Kingdom (UK) generates around 40 million tonnes (Mt) per annum of core construction and demolition (C&D) waste, excluding 30 Mt of excavation and 20 Mt of mixed wastes including inert fines, timber, metals, plastics and packaging. Across Europe (EU-15) the figure is approximately 180 Mt of core C&D waste excluding excavation and mixed, of which 28% (50.4 Mt) is reused or recycled and 72% (129.6 Mt) incinerated or sent to landfill.

Forces, such as rising disposal costs, a general increase in the environmental awareness of clients/public, and more stringent environmental legislation means that waste management will play a key role in the long-term sustainability of the construction and associated industries. This will integrate all stages of the project life cycle including design, planning, refurbishment, demolition and construction.

Given the relatively low profit margins in these industries, a leaner approach to resource use and reuse will demonstrate that reduction and recovery strategies can boost profitability and reduce the environmental impact of C&D processes. Similarly, that industry is responsive to the growing legislation and guidance generated at the Member State and Community levels.

Overview

In the UK, the C&D industries produce vast quantities of waste components and materials that for environmental, economical and social reasons is becoming unacceptable. To effectively tackle this waste issue a more proactive approach must be taken. This sees buildings as dynamic systems, operating at a number of physical and time scales, with many changes over their lifetime.

The level of knowledge on the amounts, types and location of C&D material is at best an informed and extrapolated guess. This is not surprising, as there has been little opportunity to benchmark this waste stream. Despite this, it is commendable that an estimated 3.3 million tonnes of architectural and ornamental components are salvaged each year in UK for reuse. Similarly, that 24 million tonnes of recycled aggregates are recycled into mostly low-grade applications and an unknown quantity of steel is recycled back into production. However, there are large volumes of potentially reusable components other than core C&D and ornamental antiques that are currently being landfilled and lost to the system only to be replaced with similar components. In the strive for a more sustainable future and efficient use of resources, the construction, demolition and waste management industries have a vital role to play in achieving a sustainable goal.

Studies by the UK Building Research Establishment (BRE) have shown that there is an array of current and proposed legislative, fiscal and policy frameworks affecting the C&D industry, and that this will become ever more stringent in the future. These initiatives are encouraged by current and proposed fiscal measures including the landfill tax, the aggregates tax, the sustainability fund, the landfill tax credit scheme and R&D funds from government and private sources.

Construction waste

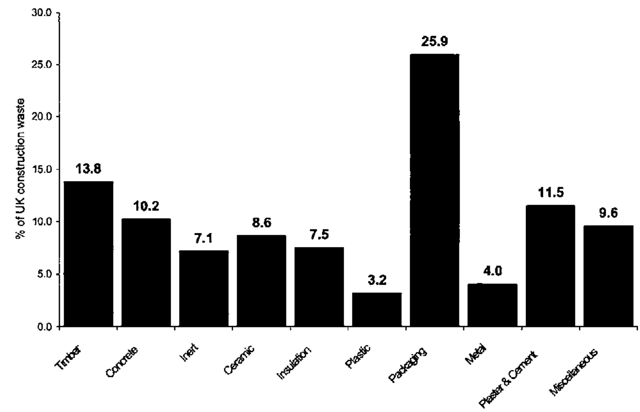
Obtaining reasonably accurate figures for the composition of construction waste has so far been elusive. 10 million tonnes of UK construction waste from sites per annum is often quoted from various sources estimated and extrapolated from disparate investigations. More recently, the BRE Centre for Waste and Recycling has been gathering detailed benchmarks of waste arisings from different types and sizes of construction, demolition, refurbishment and manufacturing sites. Further implementation of SMARTWaste™ and SMARTStart on various sites is expected to provide a more accurate picture.

The majority of construction waste goes to landfill because of the way sites are operated. Much of this waste is avoidable and reduces the already small profits of construction companies. Some estimates indicate that this waste is a large proportion of those profits – typically 25%. If 10-20% reductions in waste could be achieved, 6 million tonnes of material might be diverted from landfill saving approximately £60m in at-the-gate disposal costs. The true cost of construction waste to the industry also needs to be realised, as it includes the costs of materials, components, disposal, transport, labour to clear up, tradesperson to fix, replacement material or component, tradesperson to re-fix and lost revenue from not reusing/recycling. This true cost is significantly greater than at-the-gate disposal costs

The main wastes present in the construction waste stream are generally soil, gravel, concrete, asphalt, bricks, tiles, plaster, masonry, wood, metal, paper and plastic in differing proportions. Hazardous wastes also constitute a significant but minor proportion and include asbestos, lead, heavy metals, hydrocarbons, adhesives, paint, preservatives, contaminated soil and various materials containing PCBs (polychlorobiphenyls).

BRE has been successfully auditing waste on construction sites for three years using SMARTWaste™. Graph 1 shows that packaging 25.9% represents the greatest amount of waste from construction sites followed by timber 13.8%, plaster and cement 11.5%, concrete 10.2% and miscellaneous 9.6%. However, these figures are based on a limited number of case studies of different sizes and types but the data is believed to be the most accurate and reliable data available for construction sites. Further implementation of SMARTWaste™ on various sites is expected to provide a more accurate picture.

Graph 1. Average composition of construction waste (% by weight)



There is also a range of causes of waste on a construction site. Table 2 reveals 10 of the most common causes of the waste.

Table 2.

Common causes of construction waste	
Off cuts	Reusable packaging
Recyclable packaging	Excavation material
Temporary materials	Excess deliveries
Clearing site	No apparent reason
Office & Canteen	Unsuitable storage

Similarly, Table 3 there shows 10 common key waste products found on construction sites.

Table 3.

Common key waste products	
Plastic packaging	Timber general
Cardboard	Timber packaging
Timber pallets	Blocks
Insulation	Bricks
Plasterboard	Miscellaneous

From the SMARTWaste™ data benchmarks, Environmental Performance Indicators (EPI's) have been set up for each product group and is represented as $m^3/100m^2$. The latest EPIs for construction show that packaging has the highest EPI at $2.26m^3/100m^2$ followed by timber 1.54 $m^3/100m^2$ and concrete 1.41 $m^3/100m^2$. The average waste EPI for construction is 10.58 $m^3/100m^2$.

MEASURING WASTE – A CASE STUDY FOR THE UK GOVERNMENT

Deconstruction

Deconstruction and reuse of construction materials

BRE is currently undertaking a project on behalf of the UK Government Department of Trade and Industry (DTI) to investigate opportunities for *Deconstruction and reuse of construction materials*. Construction, demolition and refurbishment wastes represent a significant environmental and social burden on the locality of their production. This is due to the waste of resources and the use of limited landfill space. The construction and refurbishment of buildings also require a large amount of materials and products to be transported into the same area. This has the negative effect of increased traffic pollution and increased energy usage and associated carbon emissions.

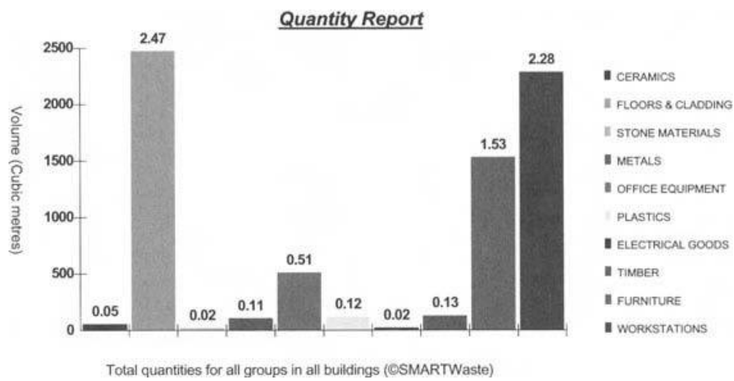
The results of this project will improve the technological performance of UK construction by increasing the lifetime of construction components and materials, thereby reducing the associated impacts of extraction, production, transport, use and disposal. The objectives of the project are to identify and advise government and industry on technical, economic and policy issues that must be addressed to make reclaimed building components and materials a viable alternative to landfill.

Case Study – Office Headquarters

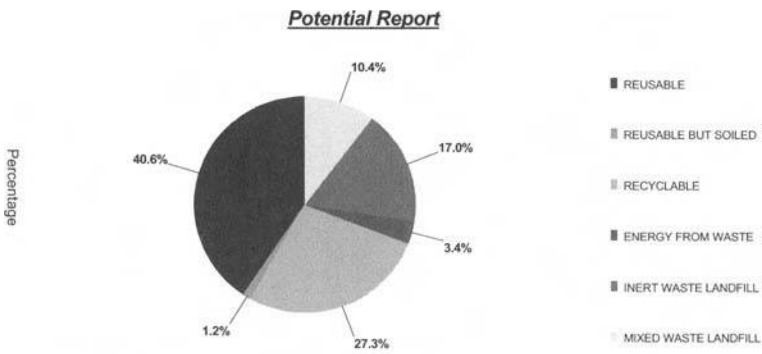
Graphs 4-5 show the overall results for one of the three case studies in terms of the quantities and optimal reuse-recycling potential of the overall waste groups. A more detailed account of components within each individual group (e.g. door, door frame, floorboards etc in the Timber group) is included in each of the final case study reports to Government. An indication of these detailed reports is included in Graphs 6-7, using metal as an example.

The case study is a collection of six 5-storey buildings in London that are due to be refurbished over a 5-year programme. A pre-refurbishment audit was undertaken to show the volumes of waste materials and products within and embodied into the buildings.

Graph 4. Quantities of materials embodied within the 5 buildings



Graph 5. Potential report for reuse, recycling and landfill



Reuse-Recycling potential for all products in all buildings (©SMARTWaste)

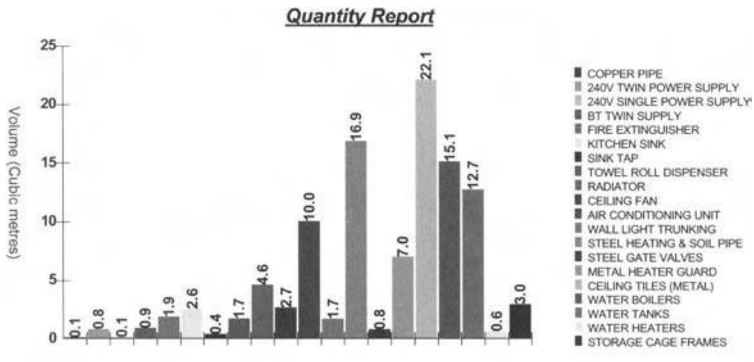
For each of the case studies, a more detailed account of each of the product groups was provided. Table 8 shows the twelve standard groups:

Table 8.

SMARTWaste waste groups	
Timber	Packaging
Concrete	Metal
Inert	Plaster and Cement
Ceramic	Miscellaneous
Insulation	Furniture
Plastic	Electrical equipment

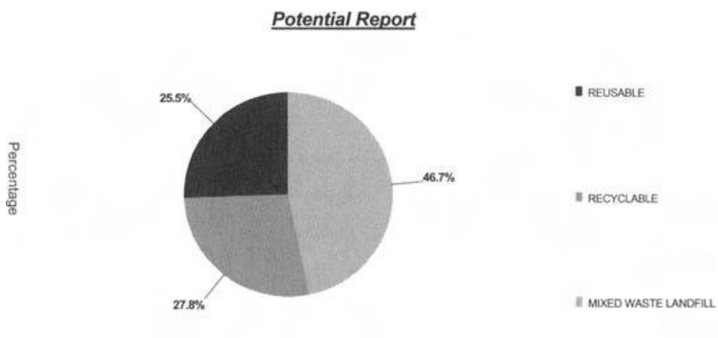
Graphs 6-7 indicate in more detail the waste products and reuse-recycling potential of the metals group for one of the case studies. Similar detail is provided for all twelve groups, and for each of the case studies.

Graph 6. Quantities of metal products in the metal materials group



Total quantities of metals for all buildings (©SMARTWaste)

Graph 7. Potential report to reuse, recycle or landfill metal products



Reuse-Recycling potential of metal for all buildings (©SMARTWaste)

The SMARTWaste™ pre-demolition and pre-refurbishment audits undertaken on a select range of buildings has shown that:

- It is possible to complete an audit of the building and its contents within a short time-frame and cost
- An audit presents greater opportunities for reuse or recycling products
- Clients are able to choose the contractor who offers best value
- Location, facilities, time, space and demand will play a vital role in balancing the decision whether to reuse, recycle or landfill

- There are untapped demands for office equipment and electrical goods
- The Client should include an audit with tender documents
- All bids should include an audit of components and materials that will be reclaimed or recovered for reuse, recycling or energy recovery
- A dedicated auditing system should be used to report on the performance of demolition contractors and to measure continual improvement.

SMARTWASTE™

SMARTWaste™

In order to achieve better waste management through waste reduction and both re-use or recycling of unavoidable waste, there is an urgent need to quantify waste arisings. SMARTWaste™ (Site Methodology to Audit, Reduce and Target Waste) has been developed by BRE to provide a robust and accurate mechanism by which wastes arising can be benchmarked and categorised by source, type, amount, cause and cost. Audits have been completed for construction, demolition, refurbishment, manufacturing and pre-fabrication. The data is a springboard to identifying and prioritising actions to reduce waste (producer responsibility), re-use at source (proximity principle), and maximise recovery to extend materials' life-cycle. The benefits of the software tool identify the potential true cost savings of projects, and maximise the reduction, reuse, recycling and recovery options of materials. Further examination of the software provides a range of features, instant reporting tailored to clients needs, sharing of information, establishing environmental performance indicators, and development of integrated material waste management strategies.

SMARTStart and SMARTWaste™

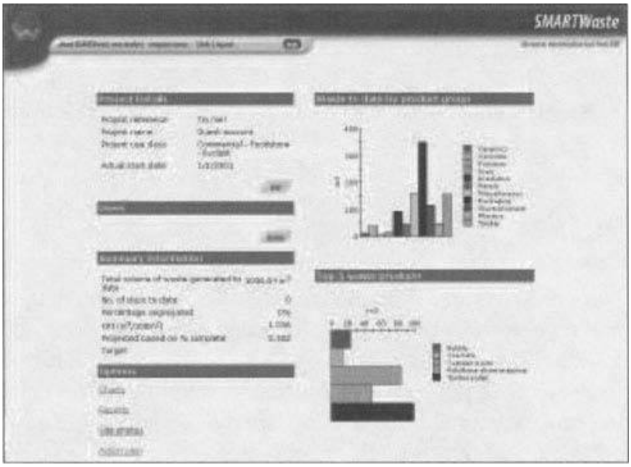
The latest version of SMARTWaste™ is a web-based (www.smartwaste.co.uk) waste auditing tool with UK construction industry benchmark data on waste targets, environmental performance indicators and practical advice on waste reduction. There are two choices of auditing. The first is a cut-down version of SMARTWaste™ that requires information to be input on estimated breakdown of material type per skip with numbers and sizes of skips.

SMARTStart will allow companies to begin the process of evaluating waste management across all of their sites. It allows each site to enter data in a very simple format to provide an EPI for individual sites and on a company-wide basis. This can be compared against national averages to measure performance and to compare with industry. It can also monitor waste reduction and recovery changes that are put in place, providing information that can benefit the whole organisation. The system is quick and simple, requiring only a visual assessment of 12 broad materials categories (Table 8) including concrete, furniture, insulation and timber. More detail on these categories is available in the comprehensive online help.

The full version of SMARTWaste™ can be used to identify further waste prevention and develop targeted material waste management strategies that focus on action plans and key waste products. Sites or companies who are finding their SMARTStart EPIs higher than average will be encouraged to use the full version of SMARTWaste™ to identify and implement a waste prevention strategy. The full version of SMARTWaste™ evaluates waste as it is being generated to determine:

- Waste types and amounts
- Causes and Costs of waste
- Waste generation over time
- Waste generation per work package/ building
- Wastage rates and EPIs
- Key Waste Products

SMARTWaste project homepage



The SMARTWaste™ tool enables data to be filtered according to the project type, value, location, floor area, company, construction products, waste management contractor, segregated material, mixed material etc. This allows extrapolation data to be extrapolated on many different levels such as geographical and building type. The detail and accuracy of the data means that waste prevention measures are easier to identify and targets for waste prevention can be made confidently for further projects or phases within the same project. BRE anticipate that the full version of SMARTWaste™ will be used to identify key waste products and causes for companies/sites getting higher than average EPIs. We also expect that once clients specify maximum wastage rates in their contracts, an accurate tool such as this will be used to certify these targets have been met (or even improved upon).

In short, the overall features of SMARTWaste™ over SMARTStart include:

- Overall quantity report, that can be adapted using various filters
- Overall cause report, that can be adapted using various filters
- EPI's for project waste groups
- Project key waste products
- Project trend reports, that can be adapted using various filters
- Wastage rates of key waste products and any other selected product

- Interactive action plans for targeted wastes including targets and results
- Instant weekly and monthly reports that are automatically generated.

CONCLUSION

This paper has shown that despite the lack of suitable historic data of UK construction and demolition waste, there has been much progress since the development of the SMARTWaste™ and SMARTStart system. This paper has also shown that it is possible to develop a greater understanding of the performance of the construction process and the material wastes that generate during the whole lifecycle – from manufacture, through construction, demolition or refurbishment. As the data is collected, it is possible to monitor and filter the data and performance using a range of interactive options including waste quantities, causes, trends, wastage rates, key waste products, EPI's, action plans etc. The value of this data is to target waste management and waste reduction strategies at the key wastes and waste-generating activities in the construction process.

Despite this promising information, it is important to remember the limitation of relying on insufficient data as highlighted in this paper e.g. a 45-fold variation between the upper and lower percentile for the timber waste EPI. Hence there is a need to significantly increase the number of similar and different types of projects to be benchmarked using the SMARTWaste and SMARTStart tools both Nationally and Internationally. This paper presents a general overview of the tools which are accessible via the internet.

Finally, the scope of the SMARTWaste™ and SMARTStart tools does not end here. Although the system is currently focused on the construction industry, it is easily adapted to other waste generating activities, industries and manufacturing. It is also possible to provide a custom system for institutional organisations and associations that use the system databases tailored to their needs. It is also planned in the near future to integrate the system into a National geographical information system (GIS) and a materials information exchange sponsored by the UK Government. This, along with an increased number of registered users will surely provide a smarter means to SMARTWaste™ the construction industry.

REFERENCES

BRE Information Papers and Digests, available from Construction Research Communications Ltd, 151 Rosebery Avenue, London EC1R 4QX, Telephone +44 (44)20 7505 6622, Fax: (44)20 7505 6606, E-mail: crc@construct.emap.co.uk

- IP3/97 Demonstration of re-use and recycling of materials
- Digest 433 Recycled Aggregates
- IP1/96 Management of construction and demolition waste
- IP5/94 The use of recycled aggregates in concrete
- IP12/97 Plastics recycling in the construction industry
- IP 14/98 Blocks with recycled aggregate: beam and block flooring
- IP 7/00 Reclamation and recycling of building materials
- Digest 447 Waste minimisation on a construction site
- BR418 Deconstruction and reuse of construction materials

STEEL REINFORCEMENT CONCRETE STRUCTURES: AN OVERVIEW ON THE BRAZILIAN PRODUCTION METHODS

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ABSTRACT

This paper is a result of an academic research conducted between March 1999 and May 2001 at the University of São Paulo, Brazil, which aimed to characterize the main technologies and management approaches in producing building concrete structures[1].

Based on this research, this paper divides the structure production into three subtasks: formwork, steel reinforcement and concrete placement. For each subtask, based on a survey with 207 construction sites, it describes systems adoptions , materials acquirement and labor hiring approaches. Moreover, the relative incidence of the different alternatives is evaluated.

SUMMAIRE

Cet article résulte d'une recherche réalisée entre mars 1999 et mai 2001 à l'Université de São Paulo, Brésil, dont l'objectif est de caractériser les principales technologies et le management de la production de structures des bâtiments en béton armé. On a divisé la production de la structure en trois étapes: coffrage, armature et coulage du béton. Pour chaque étape on décris les systèmes adoptés,

l'acquisition des matériaux et la selection du personnel qualifié de 207 chantiers. Finalement, on évalue l'incidence relative des différentes alternatives.

INTRODUCTION

With a population close to 170 million people and a nominal GDP projected around US$650 billion, Brazil has the largest domestic market in all Latin America. Regardless of the criteria, the Brazilian economy has consistently been placed among the 10 biggest economies in the world, behind the major six industrialized economies - the US, Japan and the major European economies (Germany, France, the United Kingdom and Italy). It is the second largest economy in the Americas, after the United States and followed by Canada, Mexico and Argentina. It is also the second largest economy in the developing world. Brazil and China are the only developing economies to be placed among the top 10 in the world [2]. Located in the Brazilian southeast, São Paulo is the country's main important city and it has the 3rd biggest population in the world, behind Tokyo and Mexico City.

Concerning Brazilian building construction, the steel reinforcement concrete structure is the most popular frame in use, especially for medium and tall buildings. For buildings with this kind of frame, the structure production is one of the most expensive, time consuming and complex tasks in construction. Besides its cost, complexity and duration, it has a very great influence on the other tasks and on the building construction process as a whole.

With regard to the Brazilian civil construction, São Paulo is the main important site. Annually, it has about 5,700,000 square meters of new buildings[3], and consummates about 3,600,000 cubic meters of concrete, which represents 22% of the Brazilian concrete consumption[4].

This study analyzed the production of steel reinforcement concrete structures, focusing technologies and management approaches used by 35 construction companies, reaching 207 building sites, which represent 3,400,000 m² of floor area being produced.

Beyond this information, this research presents important data concerning the Brazilian construction process, although this poll wasn't based in statistical criteria.

CHARACTERIZATION OF THE PROJECTS

Aiming to mark out the data about formwork, rebar and concrete placement, the projects studied were characterized according to their use, luxury level and structural system adopted.

Concerning the building use, 157 projects were residential (76%), 48 projects were commercial (23%) and 2 projects were industrial (1%).

As far the luxury level, 64 projects were designed for luxury properties (31%), 108 projects for "medium" properties (52%) and 35 projects for "unpretentious" or standard properties (17%).

Most of the projects polled were residential and had medium luxury level. This result points out that the construction sector is concerned with the Brazilian residential deficit, where about 10 million families are homeless or are living in homes without basic infrastructure, like water, sewer or energy.

With regard to the structural system adopted, Figure 1 and Table 1 illustrate and provide more detail about the type of projects researched.

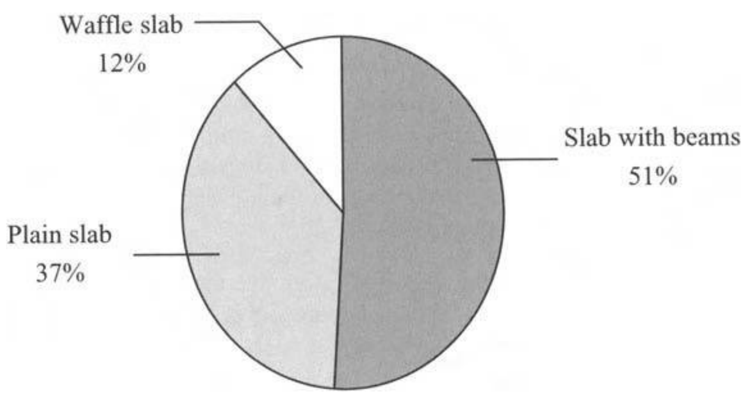

Figure 1 Project distribution according to the structural system used.

Table 1 Relative prevalence of the structural system in the building destination.

	Residential	Commercial	Industrial
Slab with beams	85 projects 54.1%	19 projects 39.6%	2 projects 100%
Plain slab	59 projects 37.6%	18 projects 37.5%	0 projects 0%
Waffle slab	13 projects 8.3%	11 projects 22.9%	0 projects 0%
TOTAL	157 projects 100%	48 projects 100%	2 projects 100%

Half of the projects adopted a conventional structural system, in which beams support slabs and columns support beams.

Plain slabs, where weighty slabs rest directly on columns, had a good incidence. While waffle slabs, which differs from plain slabs because of free spaces under the slab, making it lighter, are the least commons.

An analysis of the relative incidence of the structural system according to the building's use indicates that in residential buildings, the majority of structural systems are slabs with beams. On the other hand, in commercial buildings, the incidence of plain and waffle slabs is greater, showing the importance of the architectural flexibility, avoiding interferences between walls and beams in places with constant layout changes.

Although all the industrial buildings polled have slabs with beams, this result is unlikely, and is probably due to the low number of projects studied.

FORMWORK

Concerning formwork, three main points were analyzed: form manufacturing, formwork systems and employment practices. The first formwork analysis discusses how industrialized the manufacturing production is, dividing the discussion according to three types of mould manufacturing: timber formwork manufactured in the construction site; industrialized timber formwork; and formwork in metal or plastic (Figure 2).

The second analysis concerns the mould panels and its modularity, so the formwork systems were divided into three groups: rigid modular panels in plastic or metal; non-modular panels, normally using plywood as mould; and mixed systems, in which a construction uses both modular and non-modular systems (Figure 3).

Lastly the employment practices for formwork services are discussed. In this case, the service can be carried out by employees of the contractor, by employees of the subcontractor (while the formwork is provided by the contractor); or by employees of the subcontractor, who provides the formwork as well (Figure 4).

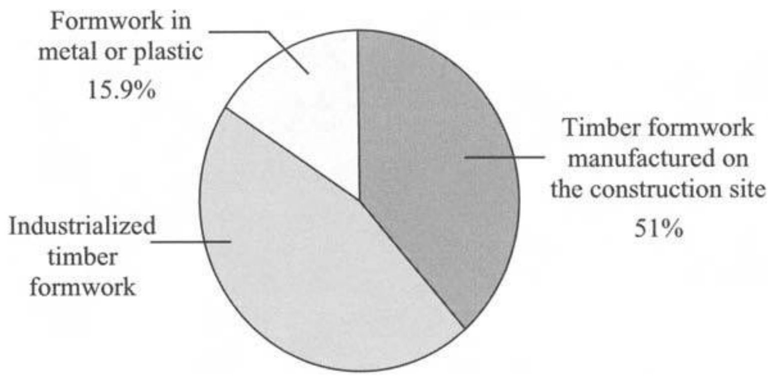

Figure 2 Project distribution according to the types of mould manufacturing.

Table 2 displays, for each kind of structural system, the distribution of the types of mould manufacturing.

Table 2 Relative prevalence of the mould manufacturing industrialization in the structural systems.

	Timber formwork manufactured on the construction site	Industrialized timber formwork	Formwork in metal or plastic	TOTAL
Slab with beams	61 projects 57.5%	34 projects 32.1%	11 projects 10.4%	106 projects 100%
Plain slab	15 projects 19.5%	56 projects 72.7%	6 projects 7.8%	77 projects 100%
Waffle slab	4 projects 16.7%	4 projects 16.7%	16 projects 66.6%	24 projects 100%

It can be seen that in the conventional structural systems (slab with beams), most of the projects used formwork manufactured on the construction site (58%) followed by industrialized timber formwork (32%).

Industrialized timber formwork was reported in the great majority of the projects with plain slab. This option can highlight some questions, since this kind of structural system has little interference with beams. This way, the timber panels would have few cuts and it would be easier and cheaper to manufacture the formwork on the construction site. Moreover, the use of metal or plastic panels can be viable because of the big spans and reduction of beams interference.

Two thirds of the projects with waffle slabs used formwork in metal or plastic. This finding makes sense because of the relative ease of casting ribs (the small beams) using plastic moulds.

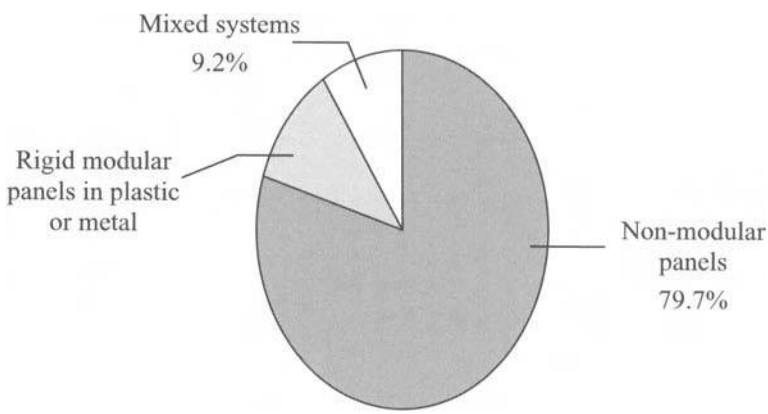

Figure 3 Project distribution according to the mould modularity and formwork frame.

With respect to the mould modularity and formwork frame, the survey indicates a strong usage of non-modular panels. Together, systems using rigid modular panels in plastic or metal and mixed systems represent about one-fifth of all 207 projects surveyed, showing a still small presence in the Brazilian market.

Analyzing the options covered in the Figure 3 according to the structural systems, the majority of projects with conventional structural systems using non-modular panels is clear (Table 3). This option can be explained relying on the toughness to use modular panels in structures with beams.

In plain slabs or waffle slabs, which have higher potential for formwork exploitation, the use of modular panels and mixed systems increases. Nonetheless, non-modular panels are still major option on these projects.

Table 3 Relativc prevalence of the mould modularity and formwork frame in the structural systems.

	Non-modular panels	Rigid modular panels in plastic or metal	Mixed systems	TOTAL
Slab with beams	91 projects 85.8%	5 projects 4.7%	10 projects 9.4%	106 projects 100%
Plain slab	57 projects 74.0%	13 projects 16.9%	7 projects 9.1%	77 projects 100%
Waffle slab	17 projects 70.8%	5 projects 20.8%	2 projects 8.4%	24 projects 100%

The adoption of pre-cast stairs for *in loco* concrete structures was also analyzed. This option appears to be a potential opportunity to improve the construction process by reducing wastes in labor and material used and also casting stairs with better quality. From the 207 projects studied, 52 adopted pre-casted stairs, which represents 25.1%.

Moving onto the materials acquirement and labor hiring approaches for formwork (Figure 4), it could be seen that most of the projects had employees hired by the subcontractor, while the contractor provided the formwork materials.

In about one-third of the projects, the contractor provided all materials and labor (without using a subcontractor for formwork services). The projects in which the subcontractor supplied employees and formwork represent only 1.5%.

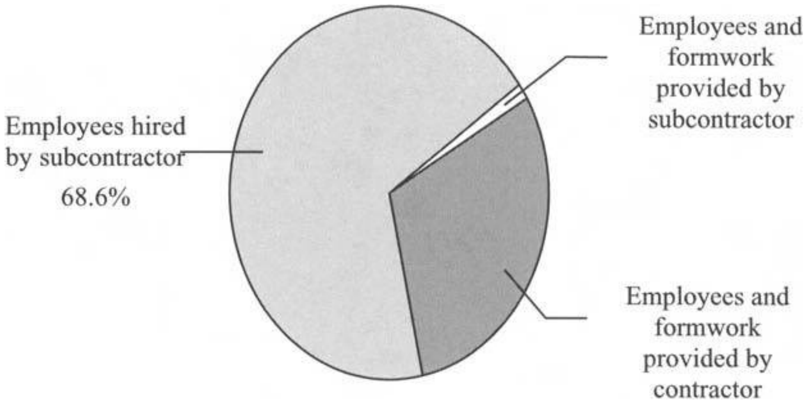

Figure 4 Project distribution according to the labor and material supplying for formwork.

STEEL REINFORCEMENT

This poll also researched how the construction companies acquired their steel and how labor and material were provided for the service.

In Brazil, the steel for reinforced concrete strutures can be purchased in three ways: as 12-meter straight bars, as cut and bent pieces (based on the structural design), and as wire gauze. According to the way the steel is purchased, the workers have more or less work to do at the construction site. Figure 5 shows a distribution of these types of steel according to the type of construction project.

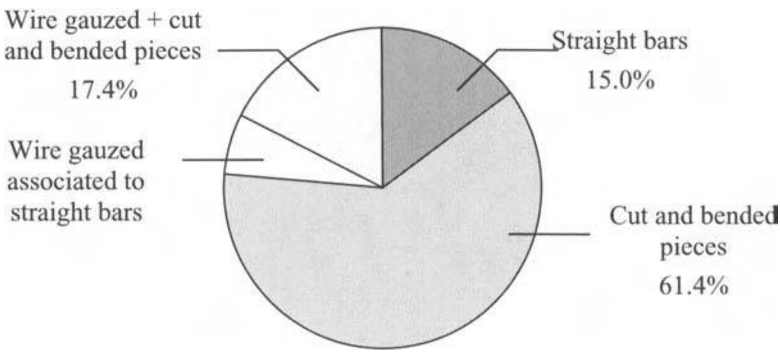

Figure 5 Project distribution according to raw steel materials.

Table 4 presents the prevalence of the raw steel materials in structural systems. The use of the steel in cut and bent pieces is predominant for projects with conventional structures and with plain slabs. However, in the majority of the projects with waffle slabs, the steel was acquired as wire gauzed attached to cut and bent pieces.

In conventional structures, where the rebar is characterized by a large number of different pieces, that make the cut and bend tasks tougher, there is an increased tendency to use pre-processed steel. Although in structures with plain slabs (where the absence of beams makes the cut and bent activities easier) there is a greater use of wire gauzed steel, as expected by these authors were.

Table 4 Relative incidence of the steel acquisition in the structural systems.

	Straight bars	Cut and bended pieces	Wire gauzed + straight bars	Wire gauzed + cut and bended pieces	TOTAL
Slab with beams	16 projects 15.1%	76 projects 71.7%	2 projects 1.9%	12 projects 11.3%	106 projects 100%
Plain slab	13 projects 16.9%	48 projects 62.3%	11 projects 14.3%	5 projects 6.5%	77 projects 100%
Waffle slab	2 projects 8.3%	3 projects 12.5%	0 project 0%	19 projects 79.2%	24 projects 100%

Similarly for formwork services, the materials procurement and labor hiring approaches for steel reinforcement (Figure 6) were highlighted by the materials purchased by the contractor and labor supplied by a subcontractor.

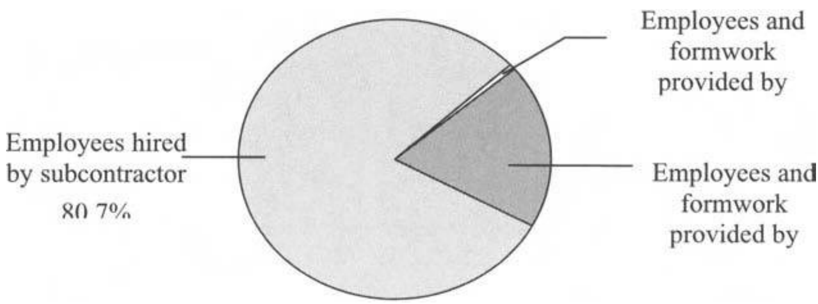

Figure 6 Project distribution according to the labor and material supplying for steel reinforcement.

CONCRETE PLACEMENT

For the cast services, three aspects were studied: the location where concrete was produced; the concrete transportation system; and how labor and material were provided for the service.

Concerning the place of the mixture of the concrete, the options included off-site location (ready-mixed concrete), or producion and mixing in panmixers at the site. However, a construction site can use both methods for the same building, acquiring ready mixed concrete and also producing it at the site. Figure 7 presents the distribution of projects according to the location where concrete was mixed.

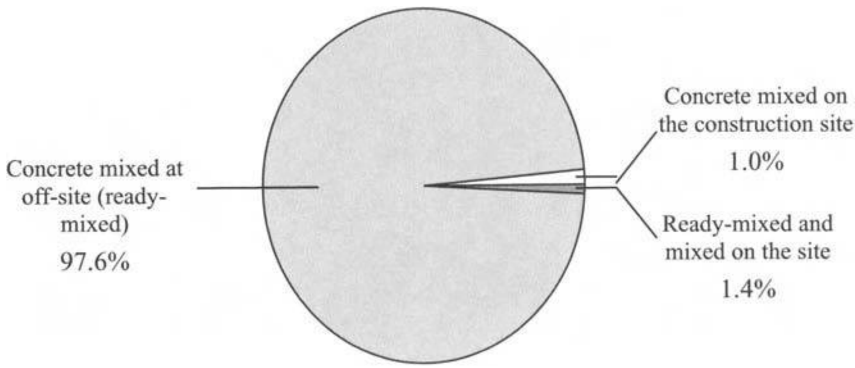

Figure 7 Project distribution according to the place of mixture of the concrete.

Due to the difficulties related to the concrete mixture on the site, such as having accurate technological controls, adequate space and slow production, this practice has been avoided in medium and large building construction.

Regards to the concrete types of transportation systems, it can be used to carry concrete may include: concrete pumps, cranes or elevators. Again, it is possible for the same construction to utilize more than one transportation system. Figure 8 shows the project distribution according to the concrete transportation systems.

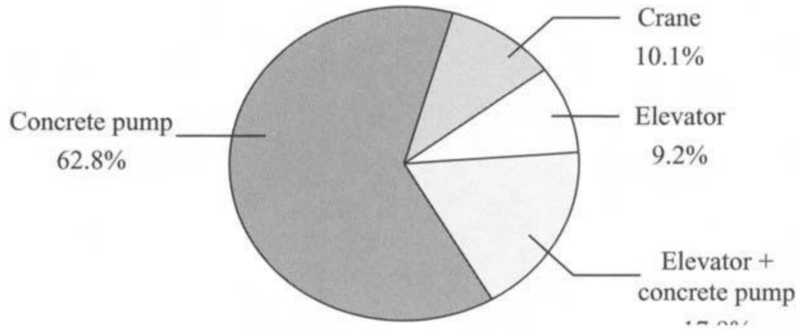

Figure 8 Project distribution according to the concrete transportation system used.

Analyzing the concrete transportation systems based on the structural systems (Table 5), these authors didn't note any appreciable trends or patterns. However, the projects with plain slabs, normally associated with large volumes of concrete, have proportionally less incidence of concrete pumping than projects with waffle slabs or conventional structures. These authors understand that structures with larger volumes should use transportation systems that allow faster placement, such as concrete pumps.

Chart 5 Relative prevalence of the concrete transportation system in the structural systems.

	Concrete pump	Crane	Elevator	Concrete pump + elevator	TOTAL
Slab with beams	67 projects 63.2%	7 projects 6.6%	5 projects 4.7%	27 projects 25.5%	106 projects 100%
Plain slab	42 projects 54.5%	14 projects 18.2%	14 projects 18.2%	7 projects 9.1%	77 projects 100%
Waffle slab	21 projects 87.5%	0 project 0%	0 project 0%	3 projects 12.5%	24 projects 100%

As with formwork and steel reinforcement services, the materials procurement and labor hiring approaches for concrete placement (Figure 9) were highlighted by the materials purchased by the contractor and labor supplied by a subcontractor.

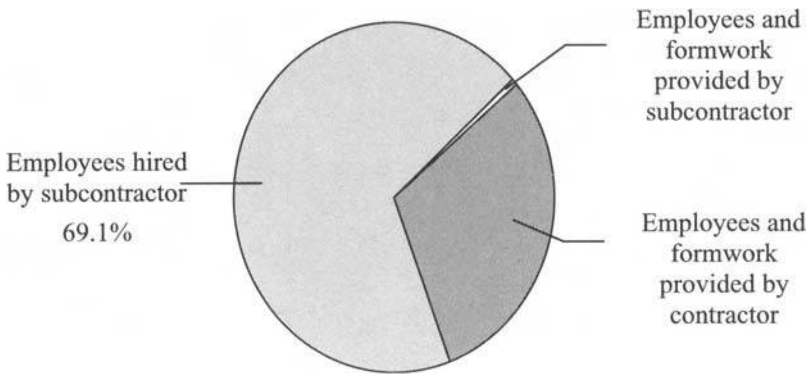

Figure 6 Project distribution according to the labor and material supplying for concrete placement.

FINAL CONSIDERATIONS

In concluding this research, the authors observed many technological and managerial approaches for steel reinforcement concrete structures production. Although this research does not provide a detailed statistical analysis, the importance of Sao Paulo and the relatively large number of construction sites researched allow it to point out some general trends that exist in the Brazilian concrete structures production. These considerations are listed below.

- Although the authors observed some tendencies to use technological improvements, most projects still rely on traditional formwork, using much wood and manufacturing components at the construction site.
- In the rebar services, an important change toward processes' improvements was noticed. This change is result of the acquisition of steel as cut and bent pieces. On the other hand, the use of wire gauzed steel is still low, especially in plain slabs.
- Very few projects produced concrete on-site, indicating that the contractors are more concerned about the concrete quality. Moreover it confirms a tendency to take out of the site the production of material and components.

- For the three construction services studied – formwork, steel reinforcement and concrete placement – it could be observed a trend towards between 67 and 80% of labor subcontracting, confirming other studies results[5]. However, this trend was not observed in material subcontracting.

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A Decision Support System for the Selection of Trenchless Technology Methods for Rehabilitation of Underground Pipeline Infrastructure

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ABSTRACT

Trenchless technology is the fastest-expanding technology affecting the world's construction industry today. Generally, trenchless technology refers to a methodology for assessing, replacing, upgrading, or expanding underground infrastructure systems with a minimum of surface disruption. The potential for trenchless technology applications is enormous. Estimates of underground infrastructure capital requirements over the next decade range in the hundreds of billions of dollars for North America alone. The need for technology that can repair and expand underground infrastructure without extensive surface disruption is accelerated as the public becomes more aware of the environmental effects and true social costs of conventional construction. This paper describes selected aspects of a computerized environment in which the user can formulate and evaluate alternative trenchless rehabilitation methods for executing a specific project.

INTRODUCTION

The development of underground infrastructure, environmental concern and economic trends are influencing society and changing the technology for utility installation, maintenance, repair, and rehabilitation. Traditionally, construction has been concerned with and organized for the creation of infrastructure and structures on relatively underdeveloped sites. However, in countries like the United States where most of the infrastructure is complete, the demands for construction are changing. Public awareness of the need to conserve and protect our environment and way of life is an important factor. Added to this is the increasing pressure put on the utilities to avoid disrupting the traffic with their activities.

Trenchless technology is the fastest-expanding technology affecting the world's construction industry today. Generally, trenchless technology refers to a methodology for assessing, replacing, upgrading, or expanding underground infrastructure systems with a minimum of surface disruption. Interest in trenchless methods has been stimulated largely by the deterioration of existing underground infrastructure systems as well as by the need to expand these systems to accommodate an expanding urban population. The potential for trenchless technology applications is enormous. Estimates of underground infrastructure capital requirements over the next decade range in the hundreds of billions of dollars for North America alone. The need for technology that can repair and expand underground infrastructure without extensive surface disruption is accelerated as the public becomes more aware of the environmental effects and true social costs of conventional construction. The tools that trenchless technologies offer range from robots to microtunnelling and from closed-circuit television to cured in-place lining. Each tool has its proper application. Inappropriate selection of trenchless of trenchless tools can lead to inferior performance of the infrastructure system and poor cost-benefit ratios for the investment.

Utility engineers and contractors alike are faced with determining the best approach for carrying out underground utility work. The problem is compounded by a lack of funds, and a proliferation of methods, technologies and resources with which to perform this kind of work. This paper describes selected aspects of a computerized environment in which the user can formulate and evaluate alternative trenchless rehabilitation methods for executing a specific project. Recent developments in information technology make pursuit of better decision-making tools timely.

TRENCHLESS TECHNOLOGY

Trenchless technology is a term used to describe a family of methods of replacing, rehabilitating and installing pipes with minimal disruption above ground (Kramer *et al.*, 1992). New methods are constantly being developed (Thomas, 1997), driven by the incentives of increasing the quality of repairs or installation, minimizing social costs and decreasing project duration. In addition, the environmental concerns have caused the trenchless sector to expand rapidly during this past decade (Allman, 1997). The trenchless industry in North America is faced with the ongoing task of incorporating new technologies and management methods into their operations. New technologies and methods generally receive acceptance very slowly due to a number of factors. The risk of applying a new or unproven technology or method is sometimes perceived as being too high. One of the major obstacles to the acceptance and use of new technologies is the initial lack of understanding of capabilities of the new technology. This lack of understanding can often lead to the inappropriate use of technology, which can lead in turn to a partial or complete failure of the construction project.

Trenchless methods can be divided into two general categories (Iseley and Tanwani, 1992). The first category deals with the inspection, repair, and upgrading of existing facilities. The second category deals with the installation of new facilities. This dichotomy of basic trenchless methodologies is demonstrated in Figure 1, which shows where some, not all, of the specific technologies associated with trenchless construction fall. The present paper deals exclusively with the first category, specifically methods suitable for work with gravity buried pipeline systems.

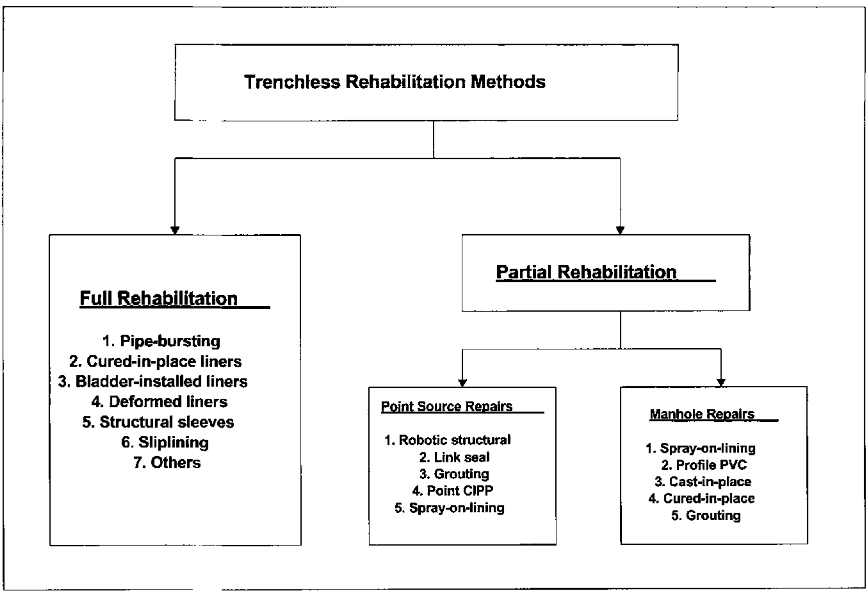

Figure 1. Classification of trenchless rehabilitation methods

There is a need for a decision-making model that can help municipal engineers understand the essential aspects of the rehabilitation treatment and help identify the strategic elements of the performance of the treatment. The use of utility theory in evaluation models is well established (Willenbrock, 1973); however, such models require the establishment of the user's utility functions. Often, utility functions are hard to formulate and can change over time. The analytical hierarchy process (Skibniewski and Chao, 1984) uses a three-level hierarchy-based model that reflects the goals and concerns of the decision maker and uses a series of criteria to evaluate rehabilitation alternatives. The comparison of the attributes of competing methods is based on determining the eigenvector for each matrix describing the attributes of each method. This method is excellent for the comparison of attributes between two methods but can become unwieldy when a large number of methods need to be evaluated, each with many specific attributes. A recent effort (Alldritt *et al.*, 1996) uses a hierarchically based model that breaks the elements of the methods under consideration into their essential physical components that describes their capabilities, and compares these capabilities to the requirements of the problem.

The selection method described in the present paper uses a hierarchy-based model that breaks the elements of the technologies under consideration into their essential physical components that describes their capabilities, and compares these capabilities to the requirements of the problem.

OVERVIEW OF SYSTEM COMPONENTS AND ITS OPERATION

Depicted in Figure 2 are the major components that we believe are essential for a computer-based methods selection system, along with some of the external issues to which such a system must respond. Outside world issues that must be dealt with include the need for tracking technological developments on a world-wide basis, the need to document previous experience and the experience of others in a readily usable form, the need to keep abreast of the regulatory climate in which work must be conducted, the need to consider a broader range of stakeholder views in the decision making process as to what methods are likely to be infeasible, especially from a socio-political viewpoint, and, the potential competitive benefits that can result from the use of developments in computer technology and electronic communications.

For the project level, a significant research challenge is to formulate representative structures that are sufficiently flexible to describe a diverse range of construction projects and methods, as well as accommodate the desire for more or less detail on the part of the system user. We have found that hierarchical structures are useful for describing both what is to be done and how to do it. There are four main components at the Project level, these being the Physical View (the project physical component breakdown structure), the Process View (the selection of pipeline rehabilitation options), the Performance Evaluation (optimization of rehabilitation options), and Output describing methods used, performance expectations, and a trace of the reasoning used by the system, if one or more knowledge-based components are used.

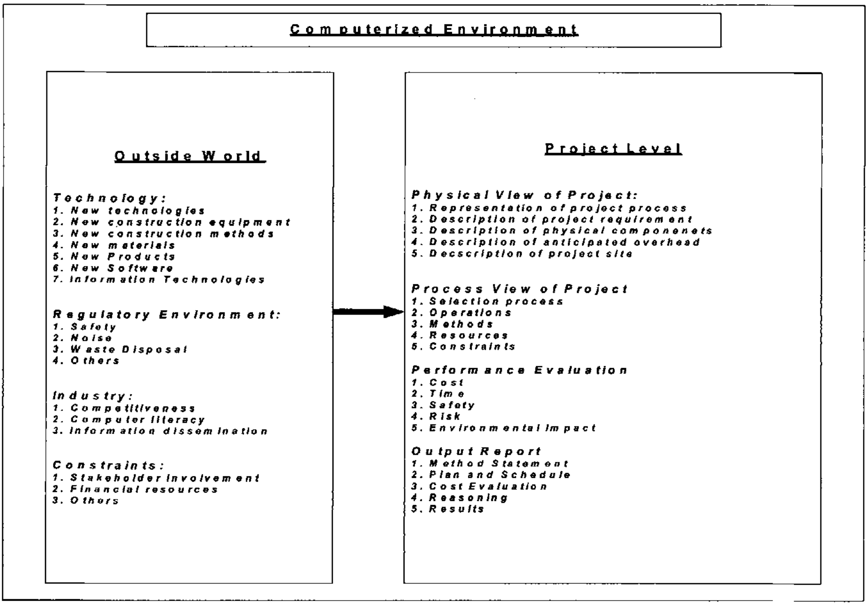

Figure 2. Overview of methods selection system components

SELECTION OF UNDERGROUND PIPELINE REHABILITATION OPTIONS

The general decision process concerning the selection of the appropriate rehabilitation method for underground pipelines follows the logical sequence of assessment, decision, and execution. These three steps are essential if the appropriate method is to be selected (Figure 3). The choice of rehabilitation selection methods is related to the technical level of a municipality, available resources and environmental concerns.

In order to select appropriate treatments for pipeline long-term preservation, it is necessary to evaluate each treatment effects in terms of functional and structural improvement over the existing pipeline. It should be noted that a pipeline performance prediction model should be modified after maintenance or rehabilitation treatment is applied to the pipeline except for the do-nothing treatment. Each rehabilitation treatment should be designed by considering the pipeline deterioration characteristics, treatment effects and the impacts of the treatment on the future deterioration or rehabilitation needs. Therefore, it is imperative to prepare a set of rehabilitation alternatives for the optimization model.

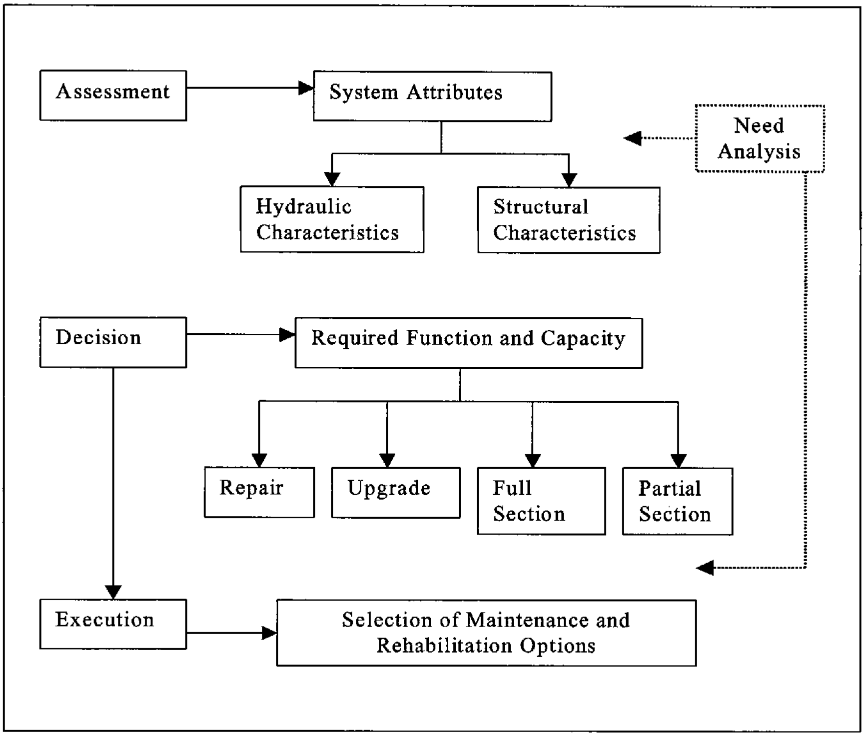

Figure 3. General decision process of selection of rehabilitation methods

The rehabilitation method selection process as described in (McKim, 1997), is the logical matching of needs to method capabilities. This system breaks the needs and capabilities into a three-level hierarchy of attribute, function, and capacity, which uniquely identifies the characteristics of both the system needs and method capabilities (Figure 4). Using the characteristics of the system, it is possible to codify the system needs in a logical manner that will clearly identify the specific needs of that system. This process allows the needs of the system to be uniquely codified using the hierarchy of attribute/function/capacity. The codification of the system needs and method capabilities allows identification of potential candidate rehabilitation methods.

The first two steps of the selection process, assessment and decision, provide the needs analysis (Figure 4). This is the process by which the condition of the existing underground facilities is determined and a decision as to the required function and capacity of each attribute is made. Assessment should provide information about the attributes of the underground system (hydraulic surface, diameter, structural capacity, and slope and line) with respect to the entire system's service requirements. Based on the needs analysis, it can be determined if either of the two main performance attributes of the hydraulic system (flow or structural) need attention. If the performance of the system is not adequate (nondesign flow rates or velocities or structural deficiencies), then the specific attributes that impact the system performance must be identified. The specific attributes are hydraulic surface friction, pipe diameter, slope/line, pipe material strength, wall thickness, and geometry (or some combination of these). The abilities of the trenchless technology-based methods to perform the required function (repair or upgrade) on a specific attribute are entirely dependent on the individual performance capabilities of each method (Erdos, 1992). Selection of the appropriate method requires that the characteristics of the method be matched with the needs of the system.

While installation issues, impact on hydraulics, and material and durability issues are key factors in the selection process, a hierarchy-based model does not explicitly include life cycle cost issues associated with each alternative. The process does not attempt to predict future pipe conditions, and accordingly life-cycle analysis is not performed. To select a final or most appropriate method, a more detailed examination of the problems and methods is required, including an economic analysis.

OPTIMIZING PIPELINE REHABILITATION OPTIONS

An approach that predicts the future condition of pipes is needed to perform life-cycle analysis for different pipe rehabilitation options. Probabilistic Markovian model similar to that shown in Figure 5 can be incorporated with dynamic programming for life cycle cost analysis of pipeline systems.

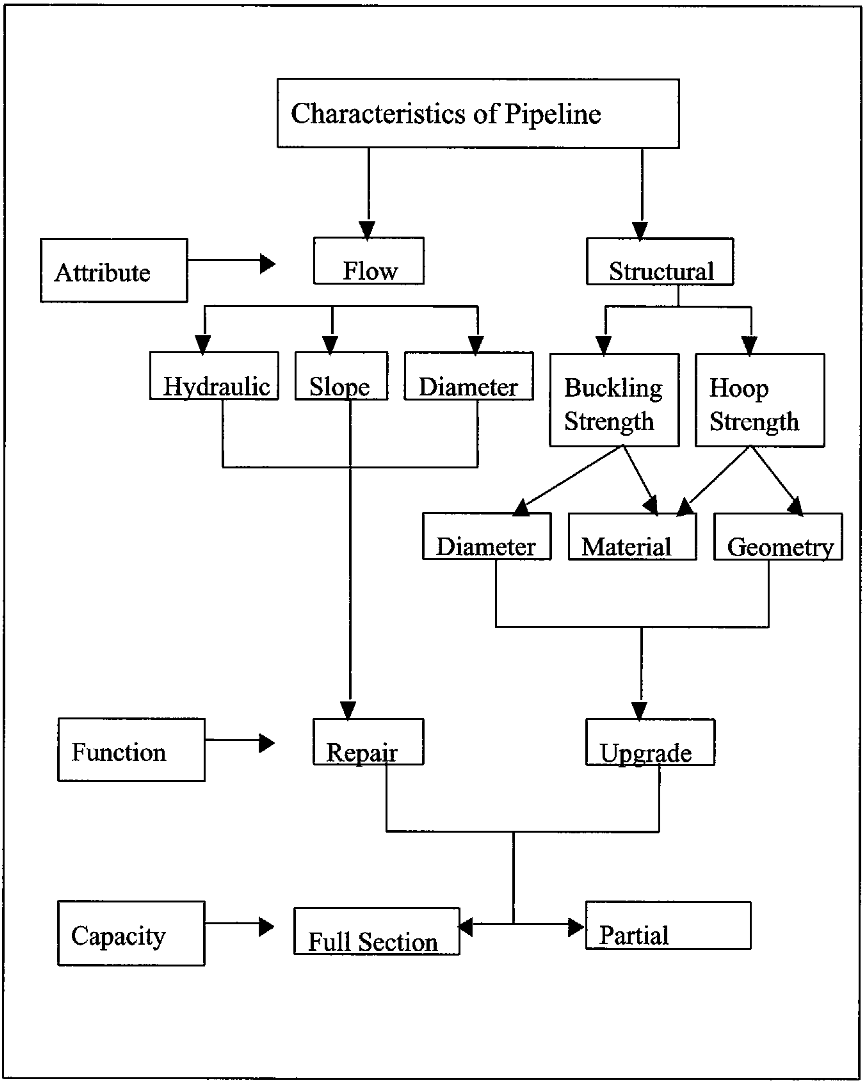

Figure 4. Characterization of system and rehabilitation methods

Dynamic programming can be employed in conjunction with a Markov probability based prediction model to obtain minimum cost maintenance and rehabilitation strategies over a given life cycle analysis period. Dynamic programming is an 'approach' to optimization, based on the principle of taking a single, complex problem and breaking it into a number of simpler and more easily solvable problems (Feighan *et al.*, 1989). An extremely important advantage that dynamic programming has over almost all classical optimization techniques is that it will, if set up correctly, determine absolute optima rather than local optima (Edens, 1985).

For a given planning horizon, the proposed dynamic programming technique provides suggestions to decision makers by optimizing total cost (or maximizing benefit/cost ratio) of pipeline system. The prediction models are Markov processes, and the results from the Markov models are fitted into the multi-year dynamic priority programming model and the output from the priority programming is a list of optimal maintenance and rehabilitation recommendation during the analysis period for each pipeline section in the network. The prioritization uses cost-effectiveness based economic analysis to utilize the limited budget with a set of maintenance and rehabilitation strategies.

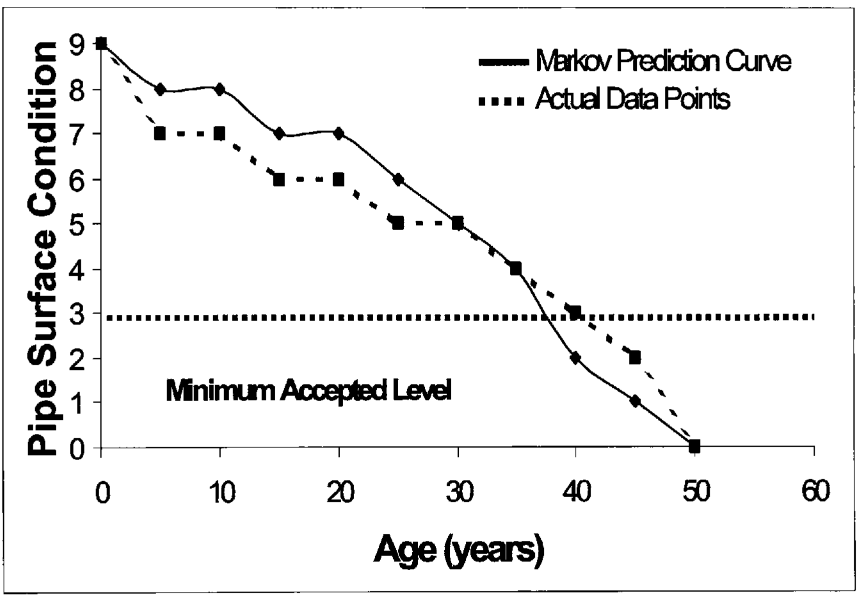

Figure 5. Markov prediction curve for underground pipe surface deterioration

CONCLUSION

This paper has described selected aspects of a computerized environment in which the user can formulate and evaluate alternative methods for executing a specific project. Ongoing work is directed at developing the rule sets required to assess feasibility of a methods statement and set of methods for a specific project, and at determining the structure and features of the evaluation module, in order to reflect owner versus contractor perspectives on cost, as well as other evaluation criteria. A short-term goal is to produce a working prototype which treats a few, prominent methods and technologies. Using the most suitable method for pipeline rehabilitation projects can save owners time and money, decrease social costs incurred by society as a whole.

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An Investigation of Construction Time Performance in Private Residential Developments

By Daniel WM Chan[1] and Albert PC Chan[2]

ABSTRACT

During the past three decades, Construction Time Performance (CTP) has often been a 'hot' issue that arouse much concern and interest of many construction researchers and industry practitioners. It is widely identified as a 'corner stone' measure of project success. Therefore, the factors that critically affect project construction durations deserve deeper investigations. This paper reports upon a funded research project which is being launched in Hong Kong to identify significant variables influencing construction durations of high-rise private residential developments. It will involve two questionnaire surveys: (1) Preliminary survey—identifying & evaluating construction time-influencing factors: The client's, consultant's and contractor's perspectives; and (2) Detailed survey—developing & testing construction time prediction model.

The industry 'duration norms' so established are of utmost benefit to building clients/ developers, design consultants, project managers and contractors, in their attempts to enhance construction output, financial flexibility, and project planning effectiveness. An outline of the relevant literature review, research framework describing the problems & objectives, research hypotheses & methodology, together with the significance of the project, will be presented and discussed herein. Interim results of this on-going project will be provided for further study.

***Keywords**: Construction duration, time-influencing factors, prediction model, private residential developments, Hong Kong.*

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INTRODUCTION

Construction researchers and industry practitioners have recently begun to emphasize the need for developing best practice benchmark measures, say for instance, of construction time performance (CTP) to be used by clients, consultants and contractors (Walker, 1994; Blyth, 1995; MacKenzie, 1996; Chan and Kumaraswamy, 1997b). This has initiated a need for raising the overall construction productivity. The burgeoning performance demands and heightened competitiveness of the Hong Kong construction industry, have triggered efforts to investigate, assess and make recommendations for enhancing industry performance, such as by Chan (1996) with reference to the determinants of project success; and by Chan and Kumaraswamy (1996a, 1996b) pertaining to the factors causing project delays.

This paper makes a prompt response to the current issues addressed in the Report released by the Construction Industry Review Committee of the Hong Kong Special Administrative Region (HKSAR) Government "Construct for Excellence"—especially in the improvements of project performance and construction productivity. In an attempt to enhance project CTP, it is essential to firstly explore the significance of different factors that affect the "construction durations" of projects in Hong Kong. Then it is necessary to develop best practice 'benchmark measures' of industry norms for overall construction periods, by modelling the durations of the primary work packages of the building construction process, e.g. foundations and superstructure. High-rise private sector housing is chosen as the target building type for study.

FACTORS THAT AFFECT CONSTRUCTION DURATIONS

The research addressed in this paper is formulated on the basis of the previous work of other researchers and the identification of gaps in knowledge with respect to CTP of projects worldwide. The literature surveyed includes the studies by Bromilow (1969), Sidwell (1982), Ireland (1983), NEDO (1983, 1988), Nkado (1991), Walker (1994), Chan (1998) and Vines (1998). The mid-1990s in Hong Kong has seen another construction boom due to the accelerated residential demand from both public and private sectors, and the ten New Airport Core Programme (ACP) projects including the new modernized airport construction at Chek Lap Kok and the related infrastructure developments. Research in the past decade, that used case study methodology to help identify factors influencing CTP, includes the investigations by NEDO (1988), Kaka and Price (1991), Nkado (1991), Walker (1994), Yeong (1994), Blyth (1995), Chan and Kumaraswamy (1995a, 1995b, 1997a, 1997b), Chan (1996), Khosrowshahi and Kaka (1996), MacKenzie (1996), Chan (1998), MacKenzie *et al.* (1999), Walker and Vines (2000), as well as Ng *et al.* (2001).

A review of the literature suggests that the construction duration of a project is affected by a vast number of factors and to varying extents. Nkado (1995) found an absence of consensus in the literature on the identification of factors which influence planned or actual construction times. However, it was proposed in a recent doctoral research exercise (Chan, 1998) that these time-influencing factors in Hong Kong can be classified into the following four major factor categories, as for example also identified in other countries (Walker, 1994; Blyth, 1995):

(a) Project-scope;

(b) Project complexity;

(c) Project environment; and

(d) Management-related attributes

The above four factor categories were explored in association with their constituent causal factors, to gain a sound understanding of their significance with regard to project construction times. Figure 1 has been developed to show the four categories and their principal associated factors that could influence project durations.

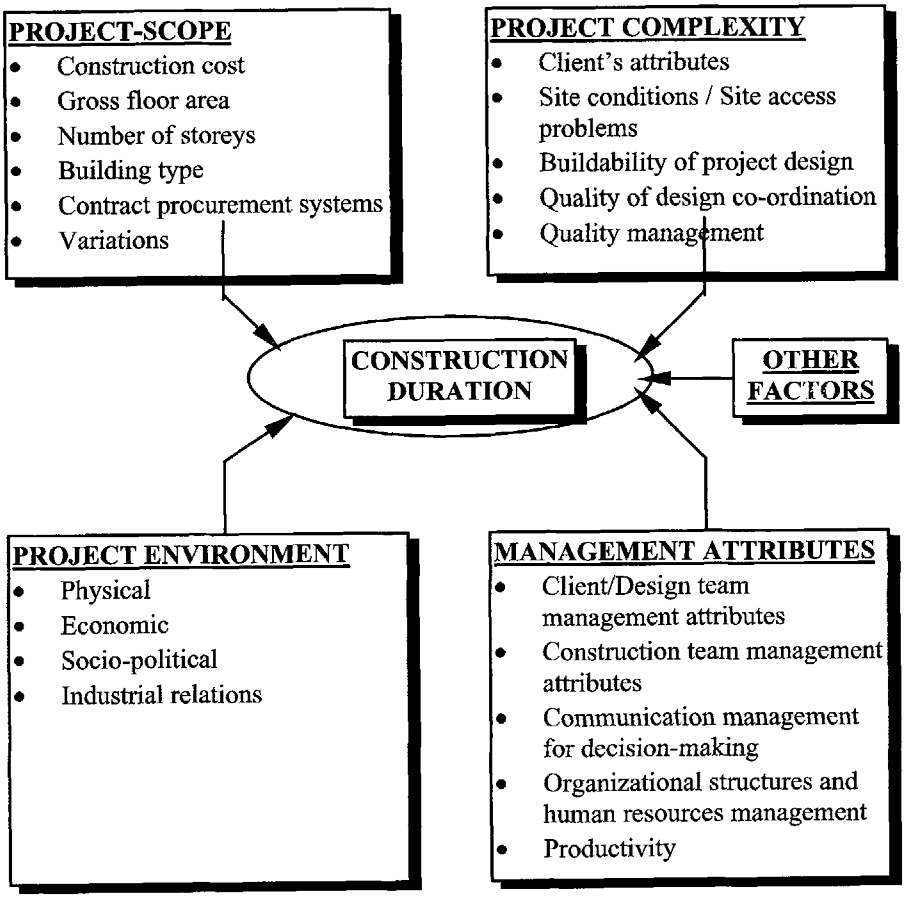


Figure 1 Summary of factors affecting construction durations of projects.

(source: Chan, 1998)

RESEARCH FRAMEWORK

Research Problems and Questions

This paper stresses on the evolving nature of a construction time prediction model. For example, major issues arising from the needs to provide pertinent answers to relevant questions in the context of Hong Kong building construction, for instance:

1. How is 'construction time performance' (CTP) of a project measured?

2. What are the significant factors affecting CTP?

3. To what extent do these factors affect CTP?

4. Why do certain factors affect CTP significantly while others do not?

5. How could CTP be enhanced?

Research Objectives

The primary aim of the proposed research project is to establish 'industry norms' for overall completion periods of high-rise private residential development projects in Hong Kong. It will involve two questionnaire surveys: (1) Preliminary survey—construction time-influencing factors: The client's, consultant's and contractor's Perspectives; and (2) Detailed survey—construction time prediction model development.

To identify and rank the significant factors which are critical in affecting the planned and actual construction durations of high-rise private residential development projects in Hong Kong from the different vantage points of key project participants;

To establish and test the relationships between the significant factors and the construction duration of such building projects; and

To suggest possible approaches to enhancing construction time performance on such building projects.

Research Hypotheses

1. One hypothesis is developed for examination in the 'preliminary survey': *'The factors contributing to construction duration of a project can be prioritized (ranked in a definitive order of importance)': i.e. each of these contributing factors affecting contract duration to different extents; and there is an identifiable relative importance of different factors affecting the construction time performance of projects.*

2. Two hypotheses are developed for examination in the 'detailed survey':

a) *'There is a general agreement among officers in the private sector client organizations and contractors, on the categorization of the common primary work packages (i.e. piling, pile cap/raft, superstructure, E&M services and finishes) and the work sequencing of these packages for the construction of a new private housing project'; and*

b) *'There is a significant predictive relationship between each of the durations for the five primary work packages, as well as of each of their start-start lag times; and a relatively small number of project-scope parameters, managerial and environmental factors'.*

All the above research hypotheses could be tested and supported by the analysis of the two questionnaire survey results and master construction programmes of relevant case study projects in Hong Kong.

Outline of Research Methodology

Sekaran (1992) proposed a useful general model of a research process for basic and applied research. The model clearly explains the process to be followed by a researcher (or research team) having a rather ambiguous idea of a potential problem worthy of research, through the development of a working hypothesis based on observation and review of the related literature which may be of great use in contributing to a testable hypothesis or set of hypotheses. These hypotheses are tested using an experiment designed specifically for the research question. Analysis of the experimental results provides answers to the research question along with explanations that can be verified, resulting in an extension to a body of knowledge.

The research methodology has been adopted by previous researchers in developing their construction time information systems and project success evaluation models (Nkado, 1991; Walker, 1994; Chan, 1996; Chan, 1998; Vines, 1998). Figure 2 demonstrates the research framework used in studying construction time performance of private sector housing projects in Hong Kong. The methods used in gleaning appropriate and sufficient data (at least 30 detailed case study projects) to test the research hypotheses and later provide valid trends and general conclusions. They include questionnaire surveys, semi-structured interviews with industry participants, case study methodology and international literature review.

1. Literature Review

A comprehensive review of the literature relating to 'construction time performance' (CTP) of projects and associated issues will be launched. Such approach is crucial in identifying the factors affecting construction durations of projects, factors causing project delays, available benchmark measures of CTP, and a variety of existing statistical models assisting in predicting project completion times. It also provides some useful insights into possible research methodology and design of the survey questionnaire for this study.

2. *Survey Questionnaire*

Simister (1995) maintained that surveys are without doubt the currently favoured research methodology in construction management. Surveys collect data in a standardized form from samples of a population and allow the researcher to reach statistical inferences based on an analysis of the data, often with the help of computers. A questionnaire is an effective and a convenient tool in survey research for observing and recording data beyond the physical reach of the observer. Based on the literature review, two sets of preliminary questionnaires will be prepared in order to explore and evaluate the factors influencing project duration as envisaged in the preliminary survey; and glean a set of project information for developing a prediction model as in the detailed survey.

3. *Pilot Study*

Self-administered questionnaires are pre-tested in a pilot study by selected experienced researchers and senior industry practitioners, and subsequently modified before a final version is produced. Fellows and Liu (1997) agreed that the piloting tests whether the questions are intelligible, easy to answer, unambiguous, etc., and through obtaining feedback from the respondents, there will be still an opportunity for improving the questionnaire.

4. *Interview Technique*

As with many other research tools, structured interviews are very powerful sources of data when used correctly, but they produce worthless data when used inappropriately (Simister, 1995). Updated information and technology development trend can be derived from industry practitioners via face-to-face or phone interviews in order to detect any disparities between theoretical studies and actual practice. This is used as a supplementary tool to fine-tune the survey questionnaire. A 'triangulation' approach is used to target the relevant staff from the client organizations, design consulting practices and construction firms for interview.

5. *Case Study Approach*

Case studies are another very powerful research methodology. They allow data to be collected in its rawest form. Case studies encourage in-depth investigation of particular instances within the research subject (Fellows and Liu, 1997). Often, case studies employ a combination of data collection methods (e.g. interviews and questionnaires), and yield deep but narrow results. Current case study projects will be identified to explore a contemporary phenomenon within its real-life context which is essential in predicting the future outcomes.

6. Methods of Data Analysis

1. Mean Score Ranking Technique;
2. Kendall's Coefficient of Concordance;
3. Spearman's Rank Correlation Coefficient;
4. Factor Analysis; and
5. Multiple Regression.

7. Research Documentation

After the data analysis and interpretation of the preliminary and detailed surveys, a comprehensive report in form of research monographs or journal papers will be compiled for dissemination of research outcomes. This can be achieved by consolidating the results of study into a coherent set of findings. Recommendations for interim implementation and further investigations will be suggested where deemed necessary. This research will add to the body of knowledge in the context of the factors that affect construction durations and benchmark measures of construction time performance on building projects, in both a national and international context.

SIGNIFICANCE OF THE STUDY

Effective Project Planning

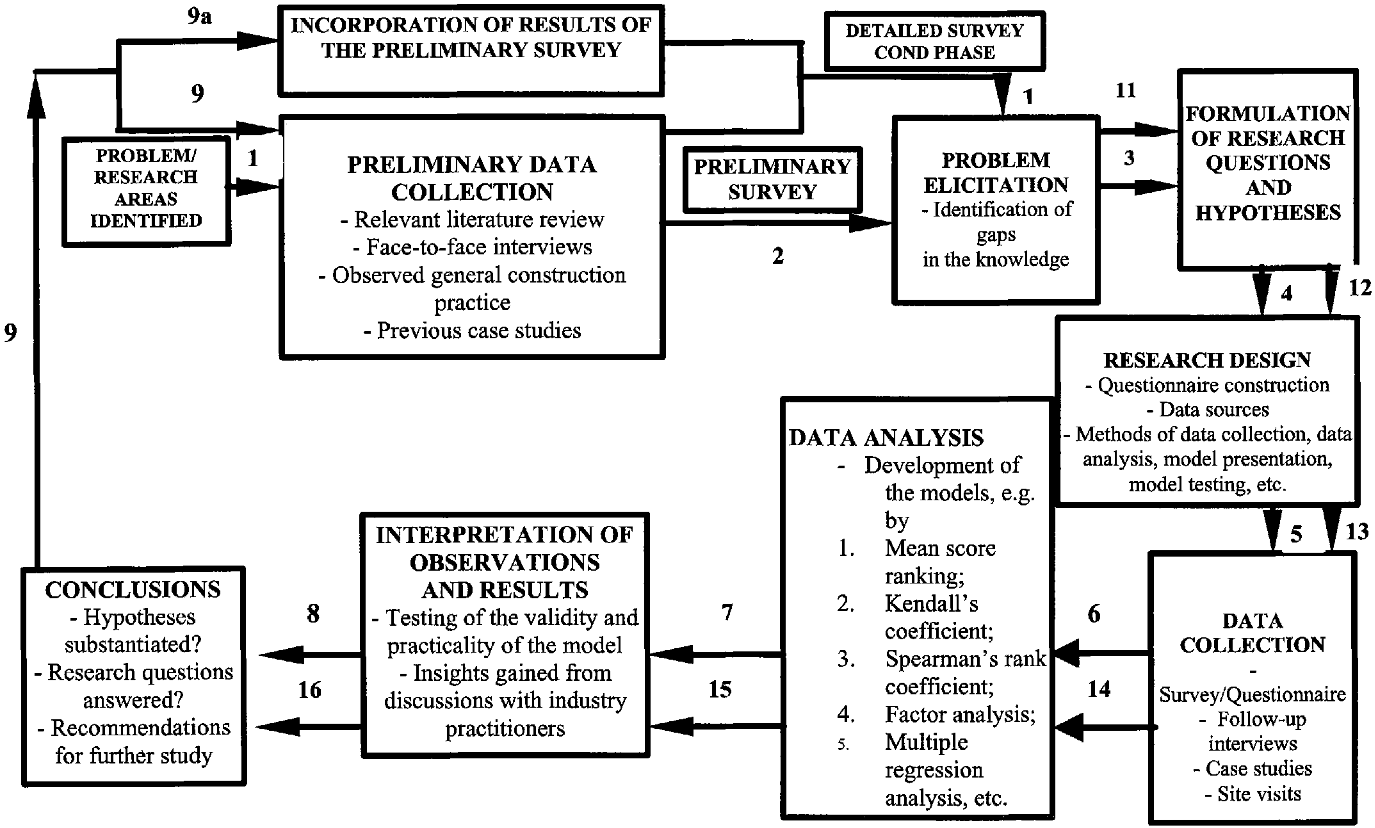
The derived prediction model will assist not only the private sector building clients/ developers but also their designers (architects/ engineers) to obtain an approximate but more reliable estimate of project construction duration in their own financial planning, tender document preparation and contractor selection (Chan and Kumaraswamy, 1995a).

Accurate Duration Estimates

An accurate completion time forecast is vital to the success of a construction project. The client has the capital investment and related interests to consider, often with no prospect of a financial return until full completion of the project (Khosrowshahi and Kaka, 1996).

Proper Cash Flow Forecasting

Pre-contract determination of the construction duration and primary work package programme is essential for proper cash flow forecasting by both the client and the contractor.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PRELIMINARY DATA COLLECTION
- Relevant literature review
- Face-to-face interviews
- Observed general construction practice
- Previous case studies
PRELIMINARY SURVEY
2
PROBLEM ELICITATION
- Identification of gaps in the knowledge
3
FORMULATION OF RESEARCH QUESTIONS AND HYPOTHESES
4
12
9
RESEARCH DESIGN
- Questionnaire construction
- Data sources
- Methods of data collection, data analysis, model presentation, model testing, etc.
DATA ANALYSIS
- Development of the models, e.g. by
1. Mean score ranking;
2. Kendall's coefficient;
3. Spearman's rank coefficient;
4. Factor analysis;
5. Multiple regression analysis, etc.
5
13
CONCLUSIONS
- Hypotheses substantiated?
- Research questions answered?
- Recommendations for further study
8
16
INTERPRETATION OF OBSERVATIONS AND RESULTS
- Testing of the validity and practicality of the model
- Insights gained from discussions with industry practitioners
7
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14
DATA COLLECTION
- Survey/Questionnaire
- Follow-up interviews
- Case studies
- Site visits

CONCLUDING REMARKS

This paper has generated a research framework of one research method to the investigation of a particular research question. A choice of research methodology, along with a brief description of the data collection instruments and data analysis tools, was offered. A body of knowledge will be expanded concerning the factors influencing construction durations and benchmark measures of construction time performance of building projects, in both national and international scenarios.

It is concluded that all of the outcomes emerging from this research project are of vital importance to further develop and refine the derived model to establish a comprehensive construction time information system to be used by clients, consultants and contractors in the future. This will enable measurement and improvement in the present levels of 'construction time performance' in private housing projects, with special emphasis on reducing construction durations in these projects. This will in turn assist in achieving the increased target output rates so as to meet the accelerated demand for housing construction in the next few years in Hong Kong.

An extensive investigation of construction time performance and its associated strategies for improvement had also been launched and results documented in another publication (Chan and Kumaraswamy, 2002). The research methodology, methods and formats developed for this study could well be extended to similar studies and duration forecasts in other building sub-sectors (e.g. private commercial) in Hong Kong, as well as in other project groups (e.g. civil engineering) in other countries, for facilitating national and international comparisons.

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AN OPEN BUILDING INDUSTRY: MAKING AGILE BUILDINGS THAT ACHIEVE PERFORMANCE FOR CLIENTS

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INTRODUCTION

Buildings must perform in response to a number of complex technical demands. Methods and criteria exist for measuring technical performance. The CIB Congress in Gavle, Sweden highlighted progress in this direction. In addition, buildings must perform in regard to a variety of complex social demands over their useful lives. In the most general sense, these social demands - having to do with both functionality (regulated and measurable) and preferences (values and choices) - can be characterized as belonging to two spheres of interests:

- Performance concerning the public good
- Performance concerning the private good

This division of performance - matching two fundamental spheres of interests - seems to hold true in all economies. These two clusters of interests - public and private - represent forces that are invariably reflected in and are in turn influenced by the built environment. They are indispensable for each other - in society as in the built fabric. Each sphere pushes for enlargement of its sphere of control, for application of resources within the space of its control, and for manifestation of its values and choices. In their balancing we find the resolution of forces that makes the built environment whole and yet capable of transformation. These forces can be found to work hierarchically, at a number of environmental LEVELS:

the community at large

the neighborhood .... URBAN TISSUE the building owner or occupants as a group .... BASE ARCHITECTURE

the individual occupant or household .... FIT-OUT

the individual person

These examples of LEVELS exist in every culture. A similar hierarchy was the basis for the Ekistics matrix developed by the Greek planner Doxiades (Doxiades, 1963) and used as a framework for research and documentation in the built environment. These levels may be more or less normalized in the regulatory and legal apparatus, and in local habits and conventions. But aside from the extent to which these are formalized, it is correct to say that built fields are organized in respect to an hierarchical structure, particularly as it has to do with division of territory, movement from one territory to another, and in the distribution of services across territorial boundaries. (Habraken, 1998)

But because buildings are not only technical artifacts but have to do with building cultures (Davis, 1999), description of buildings in either technical OR social terms only is inadequate. We must address the complexity of physical systems by describing building in a way that brings decision and control hierarchies into view with technical systems over which control is exercised.

TECHNICAL DESCRIPTION OF BUILDINGS

In North America, professionals charged with writing technical specifications use the Construction Specifications Institute's MASTERFORMAT of 16 divisions (CSI). For example, Division 4 - masonry - contains product information related to the masonry trades and systems. Division 16 - electrical - contains product information related to the electrical trades, and so on. While this alignment of products and trade jurisdiction is not absolute, there has been a long and consistent effort to relate products to trades.

Construction Specifications Institute Masterformat

division 1: general requirements
division 2: sitework
division 3: concrete
division 4: masonry
division 5: metals
division 6: wood and plastics
division 7: thermal / moisture protection
division 8: doors and windows
division 9: finishes
division 10: specialties
division 11: equipment
division 12: furnishings
division 13: special construction
division 14: conveying systems
division 15: mechanical
division 16: electrical

figure 1 (Construction Specifications Institute)

While this has been an effective tool for organizing construction documents and standardizing specification writing for decades, several difficulties result from its use as a research tool or as a basis for specifying products or systems that combine divisions. One problem is that increasing numbers of "products" incorporate elements from a number of these categories. These "hybrid" products do not neatly fit the 16 divisions. One example is "systems furniture", a "product" now widely used to fit-out large office spaces with partitions, furniture, cable management floors, air conditioning and lighting. Such complex “product bundles” - often delivered as single-sourced products with associated warrantees - cross strictly technical categories such as these.

A related difficulty is that a number of companies now own a number of subsidiaries each making discrete parts. This corporate strategy of horizontal integration is now visible internationally: e.g. the large manufacturing company Wiremold in the US has been acquired by the large French company LeGrand. Another example is the Masco Corporation, a large US corporation that manufactures and provides thousands of home improvement and building products and services through the more than 50 US and foreign companies in its worldwide family. This company has adopted a corporate strategy seeking to combine products from its parts stable in new ways aimed at the consumer market. This is requiring adjustments to supply chain logistics, marketing (including e-commece), skills training (multi-skilled workers), and perhaps adjustments to the regulatory environment.

A final difficulty in strictly technical descriptions of parts is that when one takes the point of view of the party ordering or procuring a building or a space in a building (an end user, investor, agency), interests focus not so much on the many thousands of discrete parts and their "performance" but on particular "bundles" of parts under the control of a given party such as a business renting space, a developer building a new office building, or a household making a dwelling. Usually, these "product bundles" or element groups cross CSI technical divisions. A user may not be interested in the performance of the ceiling system per se but in the behavior of the work (or living) environment as a whole. For example, a building owner will procure a building devoid of internal layouts or equipment (a "base building"). She understands that individual tenants will independently specify their own spaces, and that over time, this individualized "fit-out" will change. She and the tenants occupying the building see their work and control as organized on levels that *cross the technical classifications shown above.*

A LEVELS DESCRIPTION OF BUILDINGS

If we overlay "levels of control" on the "technical description" of buildings, we have a diagram in which we can identify performance more accurately than looking at technical systems and control separately.

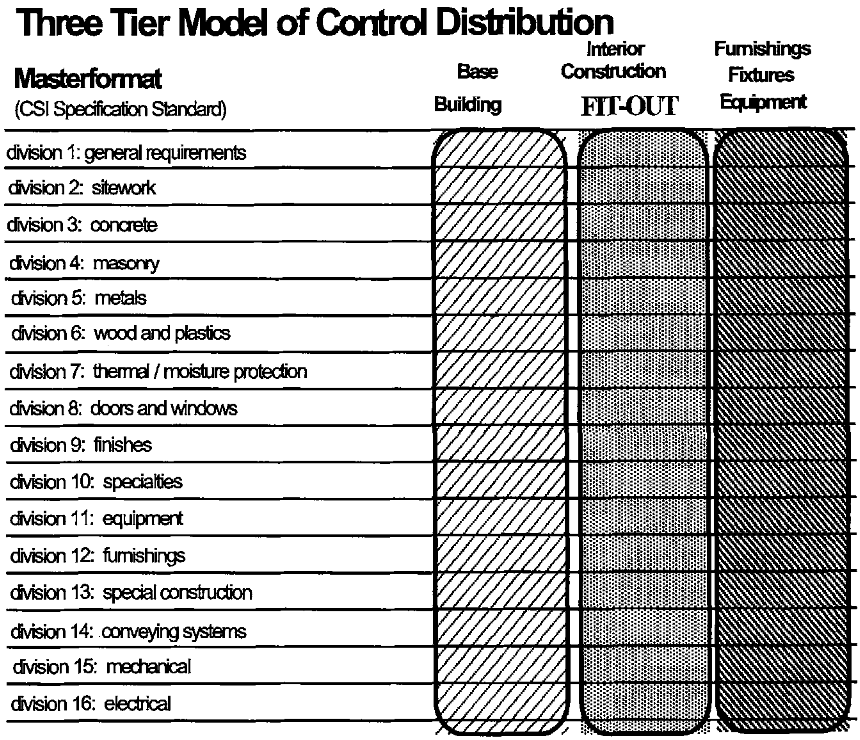

figure 2 : Three Tier Model of Control Distribution

In this diagram, we find terms conventionally used to describe the organization of large buildings. These terms - *base building, interior construction or FIT-OUT or INFILL, and FF&E* - are largely technical but are inherently related to "bundles" of elements under the control of a particular party. The *base building* is the bundle of parts and decisions that effect all occupants (structure, foundation, roof, main services, stairs, public corridors and elevators, etc) The *interior construction, FIT-OUT or INFILL* includes non structural walls, equipment, doors, lighting, and private circulation space, etc., specified per tenant. The *FF&E* is furniture, finishes and equipment also specified per tenant. (Kendall, 1999) The terms signify that "the party controlling the base building" has interest in the entire bundle of products making that environmental level. The same follows for the other "levels". In some cases, the two lower levels (Interior Construction and FF&E) are combined into single product bundles and single-sourced. An example is Steelcase's Pathways product, which, offers total slab-to-slab interior environments to the office market and is now marketed as part of a consortium offering whole buildings (Workstage.com). This overlay of control and parts tells us about performance in reality: performance concerns the inescapable interdependencies and interrelations of technical systems under the control of certain parties. (Dove, 2000)

CONFLICT REDUCTION, CONTROL AND TIME

Building performance focuses on reduction of conflict and optimizing value. In a dynamic society with highly disaggregated exercise of power over building decisions, there is nothing worse than having construction processes and a built environment that produce conflict among the parties involved (and the parts each controls). *The success of a performance based way of specifying and evaluating buildings must therefore account for the behaviors of - and performance specifications for - complex built environments when control over them is distributed.*

Buildings are not "lumpy" wholes that, once built, remain static. Buildings are constructed and later change by the decisions of certain parties who control the many thousands of discrete parts making buildings. Such parties exercise control by means of organizing parts into certain "bundles" convenient for their purposes.

Thus the control of parts changes hands - initially the designer controls parts, then the contractor takes them in hand, and finally the user gains control of the parts and, in time, changes them to suit specific preferences, and so on. But change is not uniform within a built field or a building, nor is it continuous. Observation over a period of time reveals certain patterns of stability and patterns of change. Many agree that these patterns of change can be described according to levels, connecting technical systems and those parties exercising control.

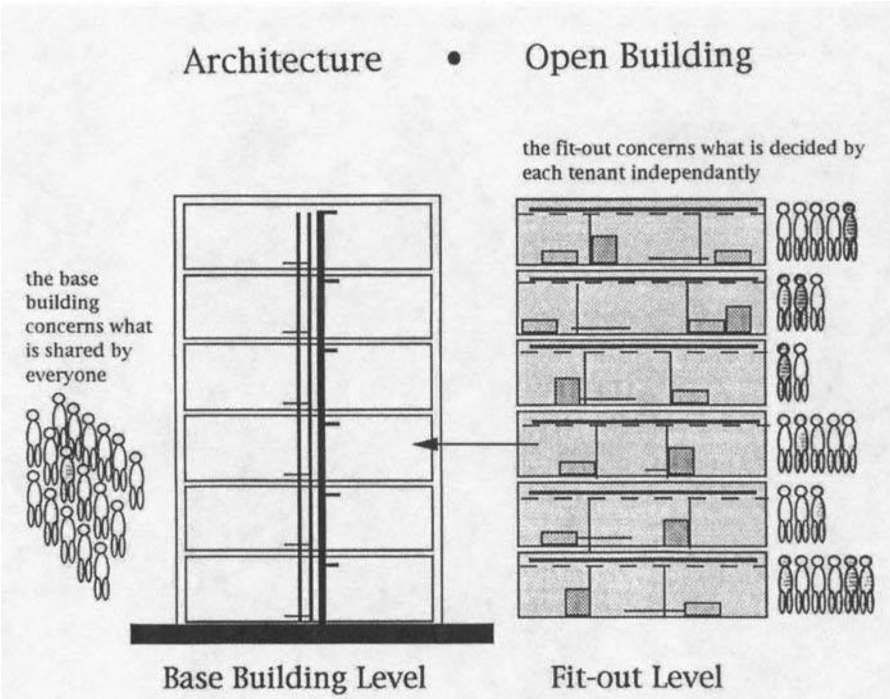

figure 3 Distinction between a Base Building and a Fit-Out Level (Kendall)

Defining performance has always been difficult. (Blach and Christensen, 1986)(Russell, 1981) Agreements concerning terms of reference and operational definitions have been illusive for all but the most technical measures. In part the difficulty has arisen from the separation of issues: questions of “control” (i.e. who decides about what, when) have largely been avoided from technical discourse because they involve power. Yet, the use of levels can lead to an improved use of the "performance concept", linking use and products, control and technical description.

USING LEVELS TO MAKE RESIDENTIAL BUILDINGS PERFORM BETTER:

A recent book - RESIDENTIAL OPEN BUILDING (Kendall and Teicher, 1999) - discusses the evolution of a way of residential building based on the idea of “performance” according to "levels" as described above. The book shows 25 buildings and a dozen infill systems developed in the process of implementing open building principles. The book also presents several innovations in organizing the finances of such buildings. The scope of the book is international and focuses on residential architecture.

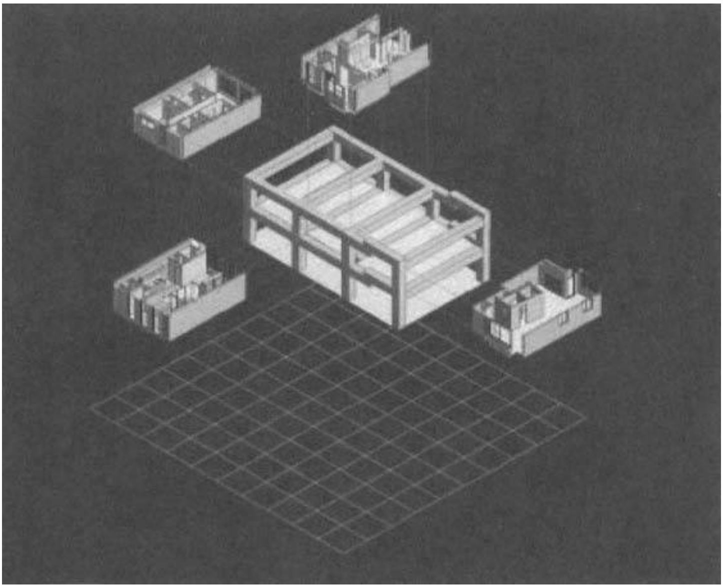

figure 4: Principle of Distinguishing Base Architecture from Fit-out (KSI Japan)

Figure 4 illustrates the basic principle found in all residential open building projects – a clear distinction between serviced base architecture and the more individual – and industrially produced - fit-out. The following projects exemplify principles that are the basis for harnessing advanced manufacturing and supply chains logistics in the service of housing for the 21st century, based on the use of levels.

NEXT 21, OSAKA, JAPAN

Built in 1994, NEXT21 is an experimental 18-unit housing project in Osaka, Japan. It anticipates the more comfortable life urban households will characteristically enjoy in the 21st Century. The project was conceived by Osaka Gas Company in collaboration with the NEXT 21 planning team. The NEXT 21 Construction Committee developed the basic plan and design.

The building frame (or "skeleton"), exterior cladding, interior finishes, and mechanical systems were designed as independent building subsystems, each with a different repair, upgrade and replacement cycle following "Century Housing

System" principles. Design of the 18 units began after design of the building frame, and continued during skeleton construction.

Individual dwelling units were designed by 13 different architects. Each unit's interior and exterior layout was freely designed within a system of coordinating rules for positioning various elements. The generous floor-to-floor height allowed for the introduction of utility distribution space above ceilings and under raised floors; therefore, ducts and piping can be routed independently of structural elements. Main beams have reduced depth mid-span allowing ducts and piping to pass over the beams without use of "sleeves" to the main horizontal utility zones under exterior corridors or "streets in the air".

NEXT21 was constructed as a whole, but designed in such a way that its various subsystems can be adjusted with improved autonomy. To test this objective, one 4th-story unit has been substantially renovated. All work was accomplished from within the unit, using hanging scaffolding, thus minimizing disruption to abutting inhabitants. A substantial amount of the materials removed - especially of the facade - were successfully redeployed to make the new facade. The project continues to explore new methods for building urban housing, experimental infill systems, and means of accommodating varying lifestyles with reduced energy consumption. The second phase of NEXT 21 includes renovating other units, introducing a new group of inhabitants, and continued evaluation of the energy systems.

Planning/Design was lead by Osaka Gas and Next 21 Planning Team (Utida, Tatsumi, Fukao, Takada, Chikazumi, Takama, Endo, Sendo). The Building Architect was Yositika Utida and the Shu-Koh-Sha Architectural + Urban Design Studio. Construction coordination and modular coordination principles were managed by Seiichi Fukao. Design system planning was lead by Kazuo Tatsumi and Mitsuo Takada. Dwelling Design Rules were formulated by Mitsuo Takada, Osaka Gas, KBI Architects and Design Office. (SD 25, 1994) (Next 21, 1994) (Kendall and Teicher, 1999.

figure5: Next 21, Osaka, Japan

PATRIMONIUMS WONINGEN / VOORBURG RENOVATION PROJECT

Patrimoniums Woningen, a large private housing association, owns a property containing many five story multifamily buildings near Rotterdam. In 1988, the association decided to rationalize management of the property and to begin to upgrade it. They decided to modernize the housing stock by renovating vacant rental units as they became vacant. At the same time, economic and facilities analysis indicated the need to begin a long-term upgrade of the entire site. Included in this work were base building improvements including the addition of elevators and balconies and upgrading the mechanical systems, and various site improvements. The owner also decided to add two-story townhouses at the corners of the large apartment blocks creating a sense of security and privacy to the inner courtyards. The original sidewalk – accessible storage rooms on the ground floor were replaced with entry level apartments for the elderly and the handicapped.

Several companies have been hired to do the dwelling unit renovations. One of them Matura Infill Systems, a company specializing in interior fit-out of dwelling units, had developed an advanced system based on open building principles. Their product has been used to fit-out a number of the units on a one-at-a-time basis.

During the two weeks required to gut out each newly vacant unit, the new tenant met with the architect. A floor plan and equipment and finish specification were selected from among several options. The drawings were then transmitted to Matura. One month after being vacated, the unit was again ready for occupancy with an entirely new interior reflecting the new tenant's preferences. The Matura Infill System solves the problem of horizontal routing of dwelling specific mechanical systems. It uses two new products as part of a "lower system" in which all the technical systems are organized. The more consumer – oriented "upper system" – including doors, partitions, cabinets, fixtures and finishes – are selected from available products in the open market. Together with a software system, the two new products for technical systems constitute the patented Matura Infill System.

figure 6: Delivery containers

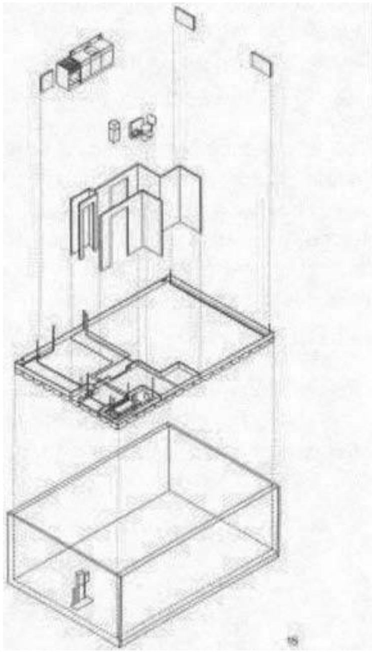

figure 7: diagram of Matura System

figure 8: Matura lower system during installation w/0-slope drainage piping in Matrix tile

BASIC PRINCIPLES FOR INDUSTRIAL PRODUCTION OF FIT-OUT

The Base Building is the permanent part of the building, providing overall serviced spaces divisible into individual dwelling units, of different sizes, so that differences in demand can be met.

The Fit-Out has to do with the individual layout within the dwelling unit, providing installations, walls, doors, utilities, kitchen and sanitary equipment and finishes.

In this way TWO DISTINCT MARKETS are served, each with its own distinct clients, time frame and products. The BASE BUILDING market is dominated by institutional clients such as investors, housing associations and private developers. Its products are in the public domain: they are site bound and are part of the political decision making process. This market is largely free of the individual consumer's selection process. Base Buildings have relatively long lives.

The FIT-OUT has the potential to develop into a true consumer market, capable of meeting the increasing variety of individual demands. Dwelling improvements in response to individual preferences made possible by rising incomes can be realized more easily. FIT-OUT - as a distinct product bundle - can effectively support the renovation of existing buildings or adaptive conversion to housing.

Clearly separating the BASE BUILDING and the FIT-OUT has distinct advantages. Technical systems in a normal housing project are embedded in the load-bearing structure, installed by a number of different trades causing interdependencies that complicate the design and construction process. Errors and conflicts are a familiar part of this work.

Open Building advocates separation of systems – particularly the equipment and utility systems – on levels. What is needed to make this separation work in practice has been extensively studied, and includes the use of "INSTALLATION CARRIERS", such as channels in the floor, raised floors, multiple ducting in the base building, special installation walls, and so on. Some of these require special provisions on the base building, others not. When existing buildings must be renovated, making specific provisions for fit-out is difficult. In that case, INSTALLATION CARRIERS as part of the FIT-OUT make sense.

When the bulk of the utility lines (drainage, cabling, ductwork) are free of the BASE BUILDING, it is easier to design and build.

Separating the production of BASE BUILDINGS and FIT-OUT means that SYSTEMATIC PRODUCT DEVELOPMENT is less difficult to achieve because DEPENDENCIES are reduced and those remaining are more manageable. THIS IS

A PREREQUISITE FOR REAL INDUSTRIAL PRODUCTION. In addition, with innovation of both products and methods of production, great variety can be achieved in a WELL CONTROLLED PRODUCTION PROCESS with INHERENT OPPORTUNITIES FOR QUALITY CONTROL.

INDUSTRIAL PROCESSES FOR FIT- OUT PRODUCTION

In the development of FIT-OUT systems, a number of challenging issues must be addressed:

1. A great variety of demand must be met in engineering, design and production.

2. Per-unit- FIT-OUT bundles demand new design, engineering, and logistics management.

3. Orders for a FIT-OUT bundle penetrates the sales, design, engineering and production process.

4. Each FIT-OUT package is a complex bundle with hundreds of details and thousands of parts.

5. Time between order and delivery is very limited.

6. A high quality end product demands a fail proof process.

To meet these challenges, efficient information management throughout the entire process is of critical importance. This means that the development of FIT-OUT systems depends on using the most advanced computer software, object-based libraries, and seamless information flows. Design databases must be linked to production and to installation work.

In the automobile industry, all of this is normal practice. The building industry is much more complex. In addition, each building site is different in many ways. The separation of BASE BUILDING and FIT-OUT is advantageous in solving the complexity of industrialization in the housing process.

INDUSTRIAL PROCESSES FOR BASE BUILDING PRODUCTION

With most of the utility and installation parts allocated to the FIT-OUT level, the BASE BUILDING can be built more efficiently. The predictability of the on-site construction process is increased by reduction of the number of independent trades and by elimination of the complexity of the installations. This enables SYSTEMATIZATION of the production of elements for on-site erection. True systematization of building provides variety, not the numbing uniformity of so-called "industrialized" buildings of the past.

THE FAÇADE: PARTLY BASE BUILDING AND PARTLY FIT-OUT

A distinction similar to the Base Building – Fit-Out distinction is also possible in the building façade. Certain parts of the façade can be decided along with the Fit-Out, within an architectural framework of permanent parts. Just as the CAPACITY of the BASE BUILDING can be studied for variable FIT-OUT, the façade can be evaluated for its capacity for individualized but partial FIT-OUT components. The NEXT 21 project is the most advanced example of this. This suggests a future industry for façade components, designed to produce variety by the way they can be safely combined to meet technical requirements.

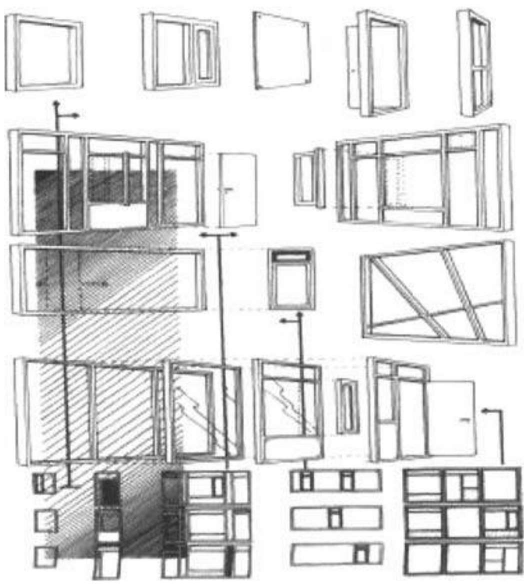

figure 9: Façade elements as part of FIT-OUT (OBOM)

CONCLUSION

The performance concept in buildings has been a guiding principle in the building research community for more than forty years. (Russell, 1981) Basing building procurement and bidding processes on desired performance rather than on specific solutions has been especially interesting to innovators interested in harnessing industrial production. Both Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) are techniques (ISO 1997) with wide acceptance in the scientific community but with insufficient application in practice.

Other methods have been developed linking cost / benefit analysis to issues of flexibility and change. (Geraedts, 2000) Still other design methods have evolved enabling a careful analysis of the "capacity" of a structure (base building) to accommodate a range of "lower level" configurations (fit-out), allowing careful calculation of spatial norms and market demands in residential construction. (Habraken, et al, 1976)

Performance is a useful concept when associated with particular products, components or systems. This paper suggests that evidence from practice and from the behavior of ordinary buildings subject to both stability and change points to the importance of the use of levels as a new way to understand performance, linking technical criteria and criteria having to do with patters of use and control.

This essay adopts the view held by those advocating the open building approach, that improving the performance, quality and capacity of buildings will occur most fruitfully when "performance" and "innovation" are aligned with principles of open building, as evidenced in the projects discussed:

- • The idea of distinct Levels of intervention in the built environment, such as those represented by base building and fit-out, or by urban design and architecture.

- • The idea that users or inhabitants may make design decisions, as well as professionals.

- • The idea that, more generally, designing is a process with multiple participants including many kinds of professionals.

- • The idea that the interface between technical systems allows the replacement of one system with another performing the same function. (As with different fit-out systems applied in the same base building)

- • The idea that built environment is in constant transformation and change must be recognized and understood to enable professionals to be effective.

- • The idea that built environment is the product of an ongoing, never ending design process in which environment transforms part by part.

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FIGURES

LOWERING HEATING COSTS : DIFFERENCES BETWEEN OBJECTIVES AND RESULTS IN FRENCH EXPERIMENTS AND THEIR CAUSES

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http://www.chantier.net/documents/theile.pdf

INTRODUCTION

A french governmental institution, the PUCA (Urbanization, Construction and Architecture Plan) promoted experiments to improve quality while lowering costs in social housing, through a program called LQCM (quality-controlled low-cost housing). Launched in 1996, this program was concluded in 2000. Between the 14 teams supported by LQCM we have selected four, that is four experiments involving more than 420 dwelling units. We selected these teams because of their innovative choices, in the french context, regarding shellwork and the heating-insulation-ventilation function.

The aim of this paper is to analyse the impact of the organization of the construction process on the performance in heating cost reduction. We first focus on the thermal approaches of these four teams and compare their objectives and results in heating cost reduction. Then, we examine what in the building process could explain differences between objectives and results in heating cost. Finally we compare the thermal performance of these four teams to other french and german experiments.

SAME COST OBJECTIVE BUT DIFFERENT THERMAL APPROACHES :

Each team participating in LQCM was composed of at least one contracting authority, an architect, and one or several building firms, each of them having their own approach of housing costs, uses and quality. Each experiment was the fruit of a collective reflection, that is a balance between the approaches of each main actor [Theile 2001]. Each team has a thermal approach. But none have the same thermal approach, though all have the same objective : the thermal approach is one of the means used to achieve a reduction of 15% in the sum "rent + service charges".

Table 1 : characteristics of the teams

	Team A	Team B	Team C	Team D
Team leader	contracting authority	main building firm	thermal consultant / main building firm	main building firm
Innovation supporter	plasterboard supplier + main building firm	main building firm	thermal consultant / main building firm	main building firm
Shellwork	discontinuous structure : steelwork + composite walls	continuous structure : composite block masonry	continuous structure : composite block masonry	discontinuous structure : concrete bearing points
Insulation	mineral wool inside walls	composite blocks	composite blocks + ventilated glazing	mineral wool on internal walls faces
Heating	radiators + individual heating system	radiators + individual heating system	floor heat + centrali-zed individual system	radiators + individual heating system
Ventilation	mechanical (V.M.C.)	mechanical (V.M.C.)	monitored natural	mechanical (V.M.C.)

grey cells indicate that the techniques used are innovative (none or little use) in the french context

In case A the contracting authority calls building firms for proposals on low cost houses, initiates at the same time a reflection on standardized plans, thinks about producing its own patented plans, but finally chooses to work with a consulting architect. In cases B and D, the main building firms initiate the reflection process and offer solutions already tried and even patented (case D). In case C, the reflection firstly focus on the heating costs and the patented solutions of a thermal consultant.

Team C has the more elaborated thermal approach of all four teams, initially defined by the thermal consultant, using a package of tested innovations : external insulation, ventilated triple glazing, monitored natural ventilation. The initial choice of structure by the thermal consultant (concrete brick and external polystyrene insulation) has been abandoned for the solution (concrete brick with integrated polystyrene insulation) offered by the main building firm. The insulation is completed by a triple glazing, allowing insulation while heating the fresh air coming from outside. So the glazing is part of a ventilation system based on monitored natural ventilation : a mini fan creates depression inside the dwellings to ensure a permanent recycling of the air. The heating is made through the floors on the basis of a semi-centralized system : each of the 16 dwelling units has a hot-water tank, the 16 tanks being heated by one small standard heater (30 Kw).

Though Team A has no thermal consultant, the thermal reflection is important. But this reflection is mainly a legacy of all the efforts, made by steel supporters, to turn buildings with metallic structure acceptable regarding residential standards. In Team A, the main building firm, a post shellwork firm specialized in plasterboard works, asked her supplier for assistance in order to win a call for proposals launched by the contracting authority. The supplier, an important plasterboard manufacturer, offered to work on a steel frame house he has already developed bringing his technical assistance. Meanwhile, a power supplier showed interest in being associated to the team to experiment electric heating, and helped in defining the insulation of the electrically heated houses. A control engineer, working for the contracting authority, supervised this work, asking for some changes in the thermal field.

In the performance approach of Team D the thermal basis is important but isn't the heart of the reflection. Like Team C, Team D includes a thermal consultant, but this one is neither a team leader nor an innovation main supporter (table 1). The core of the performance approach is built on the worksite management, through an optimization of the process.

Though a thermal consultant worked for Team B, this team has the less elaborated thermal approach of all four teams. In fact, the thermal consultant isn't part of the team : the main building firm paid him to make standard calculations validating the choices made. More, Team B benefits from the improvements, made by the thermal consultant of Team C, on the thermal characteristics of the concrete and polystyrene brick. And Team B bases its thermal approach only on the performances of this brick. That is, the thermal performance of the shellwork isn't associated to a larger reflection on insulation, ventilation and heating as for Team C and, in a lesser way, teams A and D.

The direct consequence of these thermal approaches is a reduction of heating costs, as part of a general objective of reducing by 15% the sum "rent + service charges". Nevertheless, only Team C has made direct improvements regarding the heating system, even though teams A and D had initially planned such. These improvements can be made through innovation. If all teams use innovative shellwork (table 1), they don't all use innovative insulation (Team D). And only Team C innovates in the three fields of thermal approach : insulation, temperature, ventilation. A minimum definition of a thermal approach oriented on the reduction of heating is based on actions limited to the insulation improvement. More elaborated approaches take insulation and/or heating systems into account.

THERMAL APPROACH AND HEATING COST : OBJECTIVES AND RESULTS

Only teams A and C associate insulation, heating and ventilation in their thermal approaches. Only Team C has an approach based on a global reflection about heating, insulation and ventilation : improvements in heating are linked to improvements in insulation and in ventilation. That is, the very high standard of superinsulation is conceived to allow the implementation of a peculiar heating system : the reduction of heating consumption is due to the important inertia of the shellwork (composite block masonry) linked to underfloor heating. And the conception of the ventilation is directly linked to superinsulation and heating : impact on heating performance by improvement of the insulation and pre-warming of air through the glazing ; reduction of power consumption of high standard ventilation, required by superinsulation, through monitored natural ventilation.

There is a reflection on ventilation in the approach of Team A. But it is mainly associated to the performance of façade composite light panels : the façade walls include a void, allowing a low internal ventilation, to prevent from problems of condensation. The implementation of hygro-controled ventilation was planned but finally abandoned. The implementation of heating through polyethylene pipes inside floors and façades was also planned but finally abandoned in favor of a more traditional heating system. The peculiarity of Team A is the comparison between gas heating and electric heating[1]. But this comparison wasn't linked to a reflection on heating as elaborated as Team C, and electric heating was abandoned after a test on two houses. The thermal approach of Team A is more a sum of separated actions than the result of a global heating-insulation-ventilation reflection ; despite a global reflection by the contracting authority, assisted by a management consultant, on how to define specifications for housing functions.

In Team D there is a reflection on ventilation but mainly for worksite organization purposes (multi-dwellings ventilation shaft). Team D associate insulation and heating in its thermal approach. Nevertheless, the curtain wall excepted, the innovative nature of insulation is questionnable, perhaps more for walls than glazing, in the french context (internal insulation and double sheet

[1] The possibility of electric heating wasn't studied in the other teams, the main partners believing it would be more expensive. Today, repeated increases in gas prices turned electric heating more attractive.

glazing)[2]. And the curtain wall was only implemented on one woksite and very partially. On the other side, many of the advices of the thermal consultant weren't applied, for costs choices (cool heat) but also because the choices of the conceptors (architect + main building firm) weren't compatible with the thermal consultant advice (case of centralized individual heating).

In the case of Team B the thermal approach is mainly based on the insulation performances of the shellwork : the reduction of heating costs is achieved through the improvement of insulation ; there is no particular action on the heating system (standard gas system) ; there is no particular action on the ventilation (standard mechanical ventilation). For the roofing a manufactured composite panel (mineral wool between two steel sheets) was planned, being supposed to improve the worksite organization and the roof insulation. But this panel appeared unable to meet the soundproofing requirements for residential buildings. Team B finally choose to use a standard steel panel.

Table 2 : annual heating consumptions per living m2 (objectives and results)[3]

	Team A	Team B	Team C	Team D
Comparative construction	3,53 $	3,90 $	4,40 $	4,03 $
Heating cost objective	3,12 $	3,55 $	2,09 $	3,11 $
Performance planned	- 12%	- 9%	- 53%	- 23%
Heating cost result	3,75 $ (a)	unavailable	± 4,17 $	3,11 $
Performance reached	+ 6%	unavailable	- 5%	- 23%
Nature of dwellings	twin houses (single family)	side by side sin-gle family houses	multifamily housing (G+2)	side by side sin-gle family houses
Number of dwellings	4 (+ 150)	88	16 + 4	36 (+ 125)
Construction cost / m2	530 $	544 $	609 $	647 $
Comparative construc. cost	647 $	579 $	599 $	571 $

water-heater consumption included in consumption, renting fee and maintenance cost excluded ; (a) from [Kerhuel]

[2] The product is new in the french residential context, but not the concept because internal insulation is a standard. The glazing is more innovative (low emission face) though double glazing is also a standard in France. Innovation in shellwork can't be defined in the same way than in post shellwork since the product life cycles aren't the same.
[3] Conversion made on the basis of 1 US Dollars = 7,26 Francs = 1,11 Euros.

As no draft agreement to study the gas consumptions was drawn up, between gas company and contracting authorities, we had great difficulties on obtaining heating costs results. The state of relationship between gas company and contracting authorities allowed us to obtain data for Team D but not for Team B. However, Team B could hardly reach its objective, since it had the same shellwork waterproof problem than Team C.

All these buildings know similar weather. The comparative constructions are mainly standard data ; not ever taken in the same region (case of Team C, though the differences are small). The heating results of Team C are the double of the expected (around 4,17 U$), that is the same level of the comparative constructions (4,40 U$ as average, with one at 4,25 U$). As for Team D, all inhabitants come from an old multifamily housing complex, planned to be demolished : comparing with the demolished building, rather than to a standard insulated building, would have been more interesting.

There are two main reasons for the differences between objectives and results of table 2 : the behaviour of the dwellers ; the organization of the construction process. We won't detail in this paper the dwellers' behaviour. We will only mention the most important, in terms of implications on heating cost. It should be taken into account in the case of Team D, but it also appears in table 3 (example 1) : if a dweller moves from a bad insulated dwelling to a better insulated dwelling the probability of having higher heating costs, compared to a dweller moving between houses with similar insulation, is high. We will examine now the impact of the construction industry process on distorsions between heating consumption objectives and results.

ORGANIZATION OF THE CONSTRUCTION PROCESS AND HEATING COSTS

As no thermal study (infrared camera or blower door tests) of the buildings delivered was made, we can't see in what way the differences between objectives and results in table 2 are duc to dwellers behaviour or to construction process. Though, data from our interviews allow to indicate what, in the course of the construction process, could have consequences on the heating results.

Team A :

For Team A, as for Team B, the reduction of heating costs was dcfined as rather low : the performance planned was -12 %. The performance reached is +6%, that is a deficit of 18% between objective and result[4]. We have informations about problems with insulation in the case of the electric heated dwellings : the control engineer asked to increase the thickness of the mineral wool used for insulation.

Heating consumption is 29% higher in electric fuelled than in gas fuelled dwellings, though the electric dwellings are more insulated than the gas dwellings. However, the electric heated dwellings are not included in the data for Team A in table 2. Furthermore, comparing electric and gas heating was a challenge : though cheaper in equipment, electric convectors are usually much more expensive in consumptions than gas heaters. Thus, if the modalities of insulation conception can explain differences in heating costs results between electric or gas choices, they could hardly explain alone the differences between objectives and results in table 2. Nevertheless, small defects in calculations can be ampliated by defects along the worksite, in the implementation of the building.

Actually, Team A has unusual conception organization (in the french context). The design is made under the leadership of the contracting authority, which defines, helped by an architect, standardized dwellings. And the technical conception is made according the dwelling requirements, by a plasterboard works firm helped by the technical staff of a plasterboard manufacturer. The shellwork of the building is derivated from experimental houses in which implementation the manufacturer had participated. This technical conception is followed by the contracting authority and verified by a control engineer.

This unusual organization wasn't easy to implement : two steel firms were fired from Team A before satisfactories solutions could be found for the structure conception. During the worksite, improvements were still made to the technical conception. As regards heating, the polyetylene pipes system planned was replaced by a more traditional heating system : the control engineer highlighted problems in the junctions, that weren't completely solved by the pipe manufacturer.

The implementation process wasn't more simple : the contracting authority wanted to work with small local building firms, organized in a group of firms. This group was first leadered by a economic manager, but he leaved the group, which was then leadered by the plasterboard works firm. This later deals with great part of the shellwork (except concrete fundation, steel frame and roofing), and part of the post shellwork (walls and partitioning) ; but many firms, small and with artesenal organization, are implied in the worksite. The contracting authority trained these small firms to reduce quality problems. But this group is very hard to stabilize, since many firms leave it or simply disappear (bankruptcy).

[4] We hadn't access to the data in kWh, and couldn't yet verify if the gas prices increased between objective (1996) and results (1999). Though, an increase of gas prices couldn't explain more than 1/3 of these 18%.

The implementation of this kind of building is more complex than traditional brick or concrete masonry. Mainly, in this kind of light construction, insulation is very sensitive to the quality of implementation : these walls can't insure mass inertia as in concrete, bricks or stone walls. The main building firm is stable, well organized and interested in a product of good quality. Nevertheless, the data for Team A in table 2 are relative to the first four prototypes. So it would be necessary to obtain data from the other houses (± 150) built since then, by Team, A to learn more.

Though there was some small problems in Team A with conception and implementation, we have no evidences to identify what exactly, in the construction process, could explain the difference of 18% between objective and result. Actually, this difference isn't very important in value : an average of 48 U$ per year per dwelling. Such a value doesn't represent a disfunction, an excess in heating consumptions : this difference could also be a simple result from dwellers customs.

All the same, the experiment of Team A shows, if needed, that this kind of steel frame and light panels building can reach thermal performances at least as good as fair insulated heavy masonry buildings. Of course, such or better performances can also be reached with classical masonry : the contractor of Team A is experimenting concrete block masonry for the same kind of single family houses. But, looking at the economic performance (417 U$ / m2 for the prototypes dwellings), in spite of price augmentations (530 U$ / m2 for the following dwelling units), there is still fied to achieve better thermal performance for social housing purposes. These improvements in performance can be reached by increasing superinsulation together with actions on heating system and ventilation.

Team B:

Despite our insistence, the data relative to heating consumption for Team B are unavailable. Nevertheless, the shellwork and insulation are the same than Team C, but with a classical heating. As Team B knew the same waterproof problems than Team C high is the probability of having not reached the objective, that is of having heating costs over 4 U$ / m2.

That apart, the only problem detected through interviews with Team B is relative to insulation. The steel superinsulated roof planned was abandoned, due to problems to meet soundproofing requirements : a standard steel roof was used, with the required thickness of mineral wool laid on a false ceiling. This modification isn't supposed to have visible incidence on the thermal performance of the building.

An important rain penetration defect was revealed for the walls after the conclusion of the first building. This defect represents not only unexpected costs (waterproofing treatment), but has also incidence on the heating performance of the building, since this problem is neither identified nor solved. In fact, the rain penetration problem modifies the ventilation performance of the dwelling units, with direct incidence on the heating consumption.

This waterproof defect is in law. The main building firm defines it as a manufacturing problem, and the manufacturer defines it as an implementation problem. Actually, in 1991 tests revealed a waterproof defect : cracks in the junctions appeared during sun exposure test, through which humidity penetrated during rain exposure test[5]. At that time the blocks were craft made. The craftsman went bankrupt and the manufacturer bought the patent, the main building firm promising him to buy enough blocks to insure his take off. This is why the main building insisted in modifying the thermal approach, when associated to Team C, conducing to the adoption of this composite block byTeam C.

The main building firm knew this waterproof defect. And the other partners should have been aware, at least because the results of the 1991 tests were added to the proposal submitted to the LQCM examiners. This highlight the importance of pre-implementation studies[6] : the thermal consultant of Team C asked in vain for a wall test to be built.

Team C:

Team C is the only case were differences between objective and results can be clearly attributed to the building process. Because the economies planned are so important (- 53%) that the difference between objective and result (+ 48%) can hardly be totally attributed to dwellers' behaviour. Moreover, the result of 4,17 $ per m2 is an estimation made by the thermal consultant on the basis of the first consumptions of the heaters, meaning that there wasn't enough functioning time to allow a complete slacken in the dwellers' heating behaviour.

Team C has the same superinsulation and ventilation problem than Team B, using the same concrete and polystyrene block produced by the same manufacturer and implemented by the same building firm. But the waterproofing problem of this composite masonry was less highlighted in Team C : as the heating system was more complex, and all the thermal approach entirely defined by the thermal

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[5] The waterproofing problem may be a manufacturing problem : under sun exposure the polystyrene elements and the concrete elements don't react in the same way generating small movements conducing to junctions crackings. This is only our personal understanding and this problem isn't yet scientifically solved.

[6] The lack of pre-studies is common in the french context for invitation to tender. But it don't imply problems in the usual context of residential building, since few well known techniques (concrete based) are used. The problem appear when innovative choices are taken in this context of invitation to tender for low-cost housing : the building firms engaged themselves on fixed costs basis without being sure they would build. So they didn't invest in pre-studies. And, once the project became reality, it appeared that the cost and complexity of innovation was under evaluated.

consultant the problems with masonry were probably minored during the interviews.

The thermal consultant defined a high standard of superinsulation to allow a very peculiar heating system : two heaters of 30 Kw each, working in stream, heat one or several of 16 hot-water tanks (one for each dwelling). Each hot-water tank provides warm water for sanitary use, on a side, and for underfloor heating, on the other. This system uses the inertia of the hot-water tanks and of the floors : the heaters work a few hours for heating, and then only work when there is demand from a group of hot-water tanks (train of heat).

But this thermal approach was disturbed by the main building firm and the local contractor. The main firm proposed the concrete blocks with polystyrene core already mentioned, while the local contractor criticized the external insulation, judged too fragile for social housing dwellers customs. A compromise was found : the thermal consultant tested with infrared camera the thermal performance of a house already built with these blocks, and the manufacturer modified them according the thermal consultant specifications. Team B gained by this improvement, since its first building was implemented after the building of Team C.

The thermal misperformance of Team C is partly due to the rain penetration defect described for Team B. But it is also due to problems in implementing the heating system : this system requires a very sensitive regulation that doesn't correspond to the common practices of french heating specialists. For costs purposes, the payment of the thermal consultant was limited to the conception and five work-site visits. But no pre-works studies were made. As a consequence, the charge losses are more important than planned : the two heaters have to work at the same time, and the departure temperature is 80°C instead of the 60°C planned. In fact, the thermal consultant had to intervene during the worksite more than planned, because his specifications were hardly applied. Moreover, the heater installer went in bankruptcy during the works, so the planned heating system wasn't completely achieved and the regulation work was hardly implemented.

Team C highlight, even more than Team B, the importance of implementation studies. And the conflictive attitude of the thermal consultant didn't contributed to compensate the lack of implementation studies. The architect and the main contracting firm highlighted the complexity of the heating system, especially on care and regulation. But the real problem was the lack of coordination between conception and implementation, mainly for a payment problem : to reduce the costs implementation studies and coordination were hardly done.

Team D:

The organization of the process in Team D is peculiar, divided between a concept team (an architect, a thermal consultant and the main building firm) and several implementation teams. Unlike Team A the conception is made under the leadership of the main building firm, and the standardized dwellings are conceived according the technical requirements. The building is seen as a waterproofed box : the heart of the reflection is to gain economies in building materials and worksite organization, through an optimization of the apartments distribution and layout. The reduction of heating costs is important but secondary. The façades are conceived as options improving the building aesthetics and allowing the adaptation to the local context. These options increase the cost of the basic concept.

The project is conceived, then explained to several teams who adapt and implement it. Each implementation team includes a contracting authority, an architect, and a local main building firm. The only continuity between concept and works teams is the thermal consultant, paid to make the implementation studies and supervise the worksite in the thermal aspects. But many details were forgotten by the concept team. And as the options increased the building cost, economies were made through renouncing to some heating proposals.

In one case, the concept team didn't anticipate a local site need for two buildings (11 + 14 dwellings) when a centralized heater was optimized for 13 dwellings : centralized individualized heating was abandoned for individual heating, less performant in multifamily housing. There is no incidence in table 2 since individual heating, considered more performant in single family housing, has been chosen for the building reported there for Team D (data are unavailable for the other). In all the cases, the choice of cool heating, with a departure temperature of 65° Celsius, requiring bigger and more expensive radiators, was abandoned.

Summarizing, for the building reported in table 2 for Team D, we have a rather standard superinsulation and a classical heating. The most innovative choice in insulation is a curtain wall which wasn't implemented because conceived only for multifamily buildings. Of course, the glazing (low emissive) is a real improvement of double sheet glazing insulation ; but it's thermal impact is lesser than the kind of innovation (triple glazing) used by Team C. Even more, one implementation architect revealed during the interview that he couldn't believe that the insulation used could authorize high thermal performances. Finally, a thermal label was planned and claimed for the building in table 2, but not obtained : none of the interviewed could remember why.

Nevertheless, the heating result of Team D met the objective. This is even more interesting than, for the building reported in table 2, the dwellers moved from an old housing complex with high heating costs due to bad insulation. In fact, the propensity to heat is limited by the temperature accepted as comfortable : the heating tastes of the dwellers have more incidence in heating costs than the level of insulation of their past domiciles.

This result appear not to be so good taking into account that : this is an estimation on the basis of a global gas consumption ; there is no data on the temperature inside the dwellings ; one third of the dwelling have heating cots above the average cost of 3,11 U$ (consumption above 4,40 U$ in some cases). And Team D has an higher construction cost than a conventional building : according the contracting authority similar results were obtained for cheaper through a classical call to tender. This show that possibilities to improve heating consumption through conventional construction still remain. But this also show that the level of heating cost reduction defined by the teams analysed here is low, specially when compared to german experiments.

LESSONS FROM OTHER FRENCH AND ABROAD THERMAL APPROACHES :

Two lessons merge from these four examples. One is that only a global approach, based on linked improvements on the three fields of thermal performance (insulation, temperature, ventilation), seem able to allow the best thermal performance. The second is that even the best approach can be annihilated by implementation problems, especially when improvements are based on innovation. The main causes of these problems were the following : inadequate management of quality not only among building firms but also among manufacturers (teams A, B, C) ; lack of implementation studies (teams A, B, C) ; insufficient coordination (Team C) ; details forgotten and bad anticipation of local contexts by concept team (Team D).

According [Sagot] the thermal optimization is divided in two schools : more investment in insulation and less investment in heating ; more investment in heating and less investment in insulation. However we can find examples, like a building with no insulation and quite no active heating [Hervé et al.], showing that this point of view is rather narrow. In developed countries with cold winters it's difficult nowadays to make the economy of insulation for permanent occupied residential buildings, whether in passive or active heating, except perhaps with solar or volcanic heating. None the less, thermal improvements have a cost and the financial interest of the investment depends on the heating consumption results. Let's compare now the four teams' thermal performance to other french and abroad examples, in order to enlarge the reflection to the economic and survival fields.

Table 3 : annual heating consumptions and heating choices (objectives and results)[7]

	Example 1 (gas)	Example 2 (heat pump)	Example 3 (electric) (c)	passive houses example	solar house example
comparative operation	± 10,60 U$ (a)	5,67 U$ (b)	7,99 U$	2,67 U$ (d)	2,67 U$ (d)
heating cost objective	3,74 U$ (a)	2,98 U$ (a)	5,50 U$	0,36 U$	= -12,79 U$(f)
performance planned	- 65%	- 47% (b)	- 31%	- 86%	= - 579%
heating cost result	4,60 U$ (a)	3,62 U$	4,55 U$	0,30 U$ (e)	?
performance reached	- 57%	- 36% (b)	- 43%	- 89%	?
amortization	28 years	39 years	unavailable	10 to 20 years	10 years
nature of dwellings	multifamily housing	side by side single family	multifamily housing (G+1)	single family houses	side by side single family

water-heater consumption included in heating consumption ; renting fee and maintenance cost excluded ; (a) cost of warm washing water estimated at 0,90 U$ / m2 / year ; (b) consumption of a comparative operation (standard insulation) situated in a similar region ; (c) according [Pouget], [Houlié] and [Sidoroff] ; (d) according average german data ; (e) according inquiry on Wiesbaden experimentation [Gauzin-Müller] ; (f) the exceedent electricity is sold to a power company [Lawless].

[Bézian et al.] concludes that no heating system is better than another. But this is a technical comparison that doesn't take into account conditions of building process and dwellers' behaviour. Furthermore, according the choice of heater, the consumption costs can be very different, as shown in table 3. But the economies or even profits made in consumptions can be erased by the investment costs. Table 3 indicates strong differences between active heating (examples 1 to 3) and "passive" heating systems in consumption and investment.

Comparing tables 2 and 3 the results are not so bad for teams A and C, and even good for Team D, in the active heating cases (examples 1 to 3). However, we can't make effective consumption comparisons because we don't have the average internal temperatures in all the cases. Example 1 was implemented under the

[7] As in table 2, when possible and for comparison purposes, the consumptions are calculated on a gas price basis of 0,02 U$ per kWh (price of 1996). Though, the comparisons must be made with caution.

leadership of the thermal consultant of Team C : it's a rehabilitation of a old housing complex. At an average temperature of 19°C inside the dwellings the result should be 3,04 U$/m2/year (hot water included), but the temperature measured in the first year after the conclusion of the works was 21°C (3,65 U$/m2). Then, the regulation of the heating system was transferred to a standard operator. According the thermal consultant the regulation wasn't properly made, and today the average temperature inside the dwellings is 25° C (4,60 U$/m2).

As table 2, table 3 show that important differences between expected performances and real performances might frequently happen. In example 3 the results were best than expected : it shows that when studies and implementation are properly done, and dwellers behaviour is well anticipated, the objectives can be achieved. But it also shows that electric convector continues to be globally (consumption + investment) more expensive than gas heating, even if the increase of 25% of gas prices in the late two years turn it interesting in some case.

None the less, the performances of gas and electric heating, even in the heat pump form, appears far behind the performances of "passive" heating systems. Chiefly if compared to the passive house example. Because the solar houses case is peculiar : it depends on the subsidies given to solar power systems, mainly through the obligation to power companies to buy the surplus of electricity produced.

Let's consider now the investment cost and the financial feasibility of the different solutions examined. The construction cost of teams A, B, C and D fits with the usual construction costs for social housing, even though teams C and D appear more expensive. The investment cost of a heat pump system is the double than the cost of a single gas heater similar to those used by teams A, B, and D. This heat pump extra cost (between + 5% and + 6%) fits with the financial standards in social housing, at least for Team A.

But if we consider the financial balance of contracting authorities in social housing : the economy realized by Team A, as regards the construction cost (-18%), scarcely represent the level the contracting authority has to respect in cost reduction to avoid financial collapse. So this contracting authority can't invest an extra 5%. More, according average investment cost for heat pumps in their simplest version [Fourel] and investment cost of Team D for gas heating [Raoust], the investment cost for heat pump is quite 60% higher than for gas heating. On the basis of heating results of example 2 (table 3) the amortization of this extra cost is impossible for Team D, requires 219 years for Team A, 52 years for Team C and 36 years for the worse insulated comparative construction (table 2). In social housing the amortization period hardly exceed 32 years.

Furthermore, the consumption costs for heat pumps correspond to the levels of the german thermal building specifications of 1995 (2,61 U$/m2/year). And these german specifications will be set at 1,68 U$/m2/year in 2002. So, unless substantial improvements made in active heating systems, France has to implement "passive" heating systems in order to meet the Kyoto requirements regarding the green house effect. Unfortunately, though there are experiments of passive houses in a social housing context, the building cost per m2 of a passive house would be around 1500 U$: more than the double of the building costs reported in table 2 ! Of course, we haven't the parameters of passive social houses, but even compressing the costs such a difference don't appear to fit in a compensation period corresponding to the french social housing criteria (32 years).

CONCLUSION:

The four french teams examined in this paper in the context of the LQCM program used thermal approaches in order to achieve a reduction of the sum "rent + service charges". Though the results obtained are interesting they only appear relatively good for Team D, comparing objectives and results in heating consumption. Moreover, even if these actions contribute to the reduction of CO_2 emissions, they appear misperformants as regards german actions. But they bring valious information : heating cost reduction are very sensitive to quality of studies, implementation of building, regulation and maintenance of heating systems, and dwellers' behaviour ; the financial interest of heating cost is low or even nonexistent.

In case of Team C, we have been able to see that though heating consumption is twice higher than planned, it isn't worse than the comparative operation. Therefore, it seems better to invest in systems allowing very important consumptions economies, in order to obtain interesting results despite eventual difficulties in implementation and maintenance. The choice should be made for important heating economies, staying in spite of the dweller's behaviour, allowing to concentrate on the clearance of the problems of implementation and maintenance of heating, insulation, and ventilation. Thermal choices based on the "passive house" concept or on alternative production of energy fit with this pragmatic approach. But their problem is the investment cost needed.

The problem of investment cost is triple : alternative heating systems investment costs scarcely fit with low cost housing ; the investment is made by the owner but the benefits go to the occupier ; the financial justification may appear to be weak, the investment cost being recuperated only in a medium or long term (table 3). It means that in social housing, despite of the social interest of allowing reduced heating charges to dwellers with low incomes, contracting authorities may not see an interest of extra investment in thermal improvement, thinking to their financial balance ; attitude that can be generalized to all lessor. An economic justification, linked to risks of the greenhouse effect appears to be stronger. But how to convince contracting authorities and owners that they have to invest in thermal improvement, even if buildings are responsible for 23% of greenhouse effect gazes ? The solution may appear through building specifications and taxation measures.

However, France contributes to the efforts to improve the thermal performance of buildings, even in social housing. The french building Salvatierra, part of the european project Cepheus (Cost Efficient Passive Houses as European Standard) was recently concluded. It participates in Demulog (dwellings for the poorest) an european project financing experiments using solar water-heaters and heat-pumps. In order to reach the Kyoto goals, it is important to register the consumptions on two or three years after these deliveries, and analyze the results, the possible differences with the objectives and their causes. It is also important to discuss the defects of insulation based on airproofing : mushrooms on façades ; durability and health impact of polystyrene, mineral and vegetal wools ; cleaning of ventilation shafts…

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The re-organising of construction: Design information technologies and coordination in construction practice

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ABSTRACT:

Construction work is often the subject of recommendations and initiatives to redesign strategies for increased profitability, quality and client value. However, many of the suggestions offered lack precision or direction towards particular areas or particular problems within this hugely diverse field. IT is often touted as one of the main contenders to stimulate change in construction; this paper examines a particular set of new information technologies being employed in construction design; 3D CAD. This technology is considered to extend the capabilities of 2D CAD in construction, potentially providing a robust and shared method of producing and utilising design information though the integration and coordination of all elements of design work into a single 'virtual building'. This would then be used by all involved organisations when on-site construction work is undertaken. By looking at four different adopting firms and their varying reasons for adoption, strategies for use and challenges experienced, the question of whether this technology can change the way information flows throughout construction practices, and hence reconfigure the inter-organisational configurations of construction work is examined. The analysis suggests that this is possible, and that firms using 3D CAD are realising benefits from it, but they are also experiencing some problems; in terms of the changes 3D CAD requires of existing ways of working, expectations and divisions of labour and expertise within everyday construction work.

From assessment of my research, several aspects are offered as useful to take into account when the consequences of adopting new technologies are being examined; these include expectation about the technology, the requirements of the technology to fulfil these expectations, potential tensions with existing practices and divisions of labour and the sphere of influence of the adopting organisation and the potential reach or scope of the technology itself. The implementation and use of 2D CAD is briefly considered through the frame of reference these criteria provide; using these conceptual tools the development of 2D CAD is seen as a very different type of innovation that 3D CAD, as it retained compatibility with existing practice and expectations outside of adopting organisations and hence produced little repercussion either up or downstream from the adopter's location. The

conclusions suggest that although 3D CAD is being adopted and is realising benefits, tensions exist concerning the way design information is currently produced and used and the new requirements introduced by 3D CAD. From the evidence of 3D CAD use and the example of 2D CAD adoption and development, the criteria developed are forwarded as potentially of value when regarding the implementation of any new technology.

CONSTRUCTION'S COMPLEXITY, COMPETITION & COLLABORATION:

Construction work is undertaken by a wide variety of firms and individuals, utilising many different sets of skills and knowledges; the complexities involved in the construction of even simple structures requires the participation of many different organisations. Much research into construction work, and recommendations for change in U.K. construction such as the Latham (1994) and Egan (1998) reports, starts from a set of prepositions about the adversarial nature of construction work, and the apparent lack of communication and coordination between different organisations and innovation development and adoption when compared to other areas of work, such as automotive manufacture[1]. These problems are often posited as being derived from the system of lowest-price competitive tendering used to allocate much construction work; firms are forced to tender bids with very small profit margins in order to win work. However, these bids are often prepared with incomplete knowledge about what specific work may be entailed, such as the need for specialist parts or techniques or difficult site conditions; this uncertainty combined with tiny margins for error induced by low tenders forces firms to pass on the risk through networks of sub-contractors, specialist service firms and supplier organisations. This litigious atmosphere inhibits inter-organisational relations, making long term collaboration and partnerships that extend beyond single instances or projects difficult to sustain.

This perceived view is also upheld by many practitioners; a recent survey of construction professionals questioning collaboration brought responses such as individual organisations 'don't think about the implications of their actions outside of their own envelope'. One of the main barriers to introducing collaborative technologies was thought to be lack of communication between organizations (see Fox *et al*, 2001). The idea of communication is a key issue, and one which is perhaps a distinguishing feature of construction work; although ways of winning and awarding work introduce competitive tendencies, in order to actually put up a

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[1] This immediately highlights one of the problems with reifying this notion of the 'construction industry', as it ignores the fact that a lot of the production of components and component assembly for construction work actually is factory based manufacture

building a huge amount of collaboration between many different organisations is required. In theory, competitive and adversarial relations between construction firms would be less problematic if such extensive cooperation was not necessary.

The processes involved in designing and constructing a building are complex since the 'chain' of client-designer to main contractor to subcontractor to supplier / component manufacture is in reality convoluted and protracted. Often relevant design knowledge is situated within specialist contracting or manufacturing firms, and is not available to upstream designers; often design information requires amendment due to various factors; unavailability of particular products or techniques, incompatibilities between different types of design information and unforeseen difficulties on the construction site are just a few. The fragmentation of building skills and knowledge as construction has became more complex, and large firms have reacted to economic difficulties by selling off specialist services to reduce overheads contributes to diversity in the situations of construction information; the skills and experience required to produce one building are located across many different organisational sites. Another of the key difficulties found by Fox *et al* (2001) was the gap between what designers were designing and what sorts of work and difficulties the design entailed for the contractors. Design work prior to on-site construction was thought to be less and less useful leading to view that 'drawings are only a guide' as the designers lack the information to produce useful and buildable designs.

It is into this difficult and diverse area that initiative to increase productivity, increase client value and reduce costs are released. The DETR[2] announced last year that its aim for construction is to "bring about radical change and continuous improvement in the way the construction industry goes about its business" (DETR Annual Report, 2000: 10). However, this sort of non-specific goal has to be translated into specific objectives grounded in particular ways that construction work is practiced. Without this it is meaningless.

INFORMATION TECHNOLOGY IN CONSTRUCTION PRACTICE:

Advocates for IT in construction promise that it can produce the same sorts of radical change and cost savings seen in other sectors. Stories over the last decade of Ford or Mazda's streamlining of processes using IT and subsequent huge cost cuttings sustain the call for adoption and use of available innovations (see Hammer 1990). However, technologies have to be able to survive in specific locations and provide useful functions. One such example in is 2D CAD use. 2D CAD has been a

[2] Department of the Environment, Transport and Regions but now defunct; construction is primarily part of the Department of Trade and Industry now

ubiquitous standard that has been a central part of construction design practice for many years. The ever-decreasing cost of computer hardware, the ease with which alterations could be made, and the advantages for duplication and transfer as electronic documents, as well as emerging technological professions based around use of IT in various forms signalled large scale adoption of CAD systems, in manufacturing as well as construction fields, and the redundancy of the drawing board[3]. More recently, and again perhaps mobilised by the concomitant increases in available computing power and the continual falling of hardware prices, 3D modelling has been adopted by many construction design firms as a tool to produce visualisations of potential buildings in full or part, to accompany tenders for work or demonstrate ideas to clients.

At the moment, IT in construction design seems to be expanding again; 3D CAD is being introduced into many organisations, and is being thought of as the future way of transferring information downstream from designers to contractors or fabricators, and back again. 3D CAD allows a much greater amount of information to be put into accurate digital representations of the particular building than 2D drawings; contractors using 3D designs on the building site have much access to more information about particular parts and materials and ways that different elements in the design fit together. The desired aim is to construct buildings electronically before moving to the construction site; the subsequent 'real' on-site construction being re-construction using 'real' materials. Within the model every component part is identified and specified, coordinated and arranged. Procurement can be automated, and supply on-site synchronised to the order of work derived from the model. Levels of predictability and certainty are increased and the processes of building are made more stable. This at least is the promise.

As well as configuring this vision of a harmonised future, 3D CAD can also be seen as an attempt to address some specific problems experienced in contemporary construction work. It coordinates different complex elements of building design, such as architectural, structural and the array of different building services such as electric, water and air conditioning, in the same (virtual) 3D space. This improves the buildability of the design, bridging the gap between designer and contractor worlds within construction, and lets contractors see precisely how their involvement in the construction process fits in with others. If produced early enough, 3D CAD models can also allow contractors to produce much more accurate tenders for work, and hence alleviate some of the risks of unforeseen problems they often face. 3D CAD can be seen not only as a technology with a vision of the future where it has become a new standard methodology, or accepted

[3] Perhaps not? Although not used to produce complex or final design drafts the drawing board, or at least pen and paper remains an important part of how designers do their work across many different disciplines. See Henderson 1999 for a discussion.

part of everyday work, but also as a response to particular problems experienced by specific organisations within construction fields.

Are these prospects realised in practice? With this in mind 3D CAD technologies were selected as the focal point of this research; their use touches upon both grand claims about the future and an attempt to solve specific, construction-grounded problems about coordinating information between different organisations. By examining the benefits gained and problems experienced by adopters in different organisations and in different locations in construction work an appreciation of the ability of 3D CAD to solve specific problems was assessed; through specific cases the viability of the overall vision of 3D CAD as a standard or everyday technology and set of practices could be evaluated. Four organisations agreed to take part in the research; Ove Arup & Partners (Arup), a large architecture, engineering and consultancy firm, AMEC M&E Ltd (AMEC), a mechanical and electrical services design and contracting company, Bovis Lend Lease Pharmaceutical, a specialist pharmaceutical, biotechnological and health care design and consultancy firm and Laing, a well-known contractor. In each case the CAD departments were visited, and a combination of observation of work practices and informal discussions provided information about the organisation's location within wider construction practices, the particular reasons for adopting 3D CAD technologies, the role they were playing within the organisation, the expectations about what 3D CAD could potentially do and the problems being experienced in trying to incorporate use of these new technologies into everyday work practices.

RESEARCH FINDINGS:

Location, Reasons For Adoption, Role of 3D CAD

Although located in different positions within construction work, a common feature was that the 3D technologies in all of the firms were being used in CAD departments, as a logical 'next step' from, or extension of the capabilities of, 2D CAD use. However, the different firms occupied different positions within construction work in general; from initial architectural design, through to main contractor and including specialist design and contracting, demonstrating the variety of locations where construction design can take place. Reasons for adopting 3D CAD were similarly varied. For Arup it was because of a desire to provide better quality information to contractors; a response to the present uncertainty involved in on-site phases of construction work, and the subsequent problems this can generate. AMEC, which is one of several organisations in partnership with BAA to provide construction services, and have offices at Heathrow Airport, wanted to produce a system to integrate and standardise design information and allow easier communication and collaboration with other BAA contracted firms. AMEC decided that the best way to achieve this integration was through modelling design information in virtual 3D space; 3D CAD presented a dimensionally correct way of achieving this. Bovis began to implement 3D CAD in response to the complexities of certain areas in their building designs; again 3D CAD was thought to represent the best way of both producing and transmitting accurate representations of complex areas such as laboratory plant rooms for use on construction sites.

Laing demonstrated a further motivation for adoption - as a cost cutting measure; they selected 3D CAD in order to coordinate information and avoid on-site problems, therefore sustaining profit margins. They have placed 3D CAD technologies in a central position within their whole business strategy. All design information is converted into 3D and placed within a single model of the particular building. Information from fabricators, which can change as building elements such as structural steel are manufactured, is also incorporated. All of these elements are coordinated and 'clash detected'; any dimensional or spatial discrepancies are discovered through a combination of analysis by the CAD technology and the user. Problems are referred back to the designer for amendment. Many such problems are discovered, and then rectified before actual on site construction; because of this, Laing estimate that this method of 'virtual building' saves them around 10% of the overall cost of construction.

AMEC are also pursuing a similar strategy of producing all design information in a standardised, 3D coordinated format, to allow different design elements to be easily coordinated and any problems highlighted. Also, as AMEC do a lot of refurbishment as well as new construction, they have integrated techniques such as laser mapping into their construction of 3D models. Laser mapping allows transfer of accurate on-site measurements taken during survey phases to 3D CAD models, to ensure that not only new and potential designs, but also existing construction and terrain features are accurately represented in the model. Both Arup and Bovis are experiencing increasing use of 3D modelling; Bovis estimate that at present around 20% of all design drawing and drafting work done is now 3D CAD. All of the participants were beginning to be involved in projects where all of the design information was being produced in 3D rather than in a mixture of 2D and 3D.

The Adoption Process; Benefits and Problems Experienced:

All of the firms visited felt they had made the correct decision to commit to adopting and using these technologies. It was universally felt that 2D CAD was going to be replaced by 3D CAD, and that 3D would become the standard medium of exchange for design information; the standard way of producing and transferring information between different actors involved in different phases of construction work. All also felt that benefits were being reaped. Laing especially were happy to publicly claim that the technology was saving them money. The other users felt that 3D CAD helped manage the increasing complexities of construction combined with the increasing need to collaborate with other organisations. However, although this shows that the adopters subscribe to the future vision of 3D CAD, the technology had actually been adopted because it had been considered as the solution to varied problems; for example a complex project that would have been difficult to undertake using only 2D designing.

3D CAD was being accepted as part of everyday practice by immediate users, but the adopting organisations were experiencing problems fitting new technologies into existing practices outside of their particular CAD department. Arup were trying to find effective ways to maintain the integrity of the 3D model throughout the rest of the construction process; to find ways of accessing the 3D computer based model on the construction site, and ensuring that contractors utilised the information contained within it effectively. Laing, on the other hand, as a contractor, struggled to get the necessary detailed information required to construct the 'virtual building' from designers and fabricators. 3D CAD contains and therefore requires more information than 2D CAD. Laing experienced reluctance from other firms to provide the extra information requested. AMEC had not solved the problem of how to achieve effective standards across different construction organisations and disciplines. This is also a problem of mobilising the required type and amount of information required to model in 3D and perform coordination tasks. Bovis also found the lack of standard packages and techniques to be a problem, struggling to cope with a huge array of different software packages for design and fabrication, incompatible file formats, difficulties in making design information commensurable, and non-adopters reluctant to 'take the plunge' without the presence of a strong 'favourite' in the marketplace to become the standard set of products for 3D CAD work. Both Bovis and AMEC partially resolved problems of downstream access of the 3D information; incorporating 3D into 2D drawings by including 3D views of complex areas on 2D plots for on-site or facilities management use.

These organisations are all very different and performing different tasks. Their reasons for adopting these 3D technologies also varies, for example as a coordinator of information, as a method of building in virtual space, as a way of dealing with complexity. All experience a combination of benefits and problems, but in spite of this all of the firms still subscribe to a vision of the future in which 3D is normal practice.

Table 1 Summary of firms' use of 3D technology

Organisation	Location	Main Reason for Adoption of 3D technology	Problems experienced
Ove Arup & Partners	Design consultants; between client and contractor	Need to provide better information to contractors	Maintaining integrity of information in 3D model downstream
AMEC M&E	M&E design	Integrated and standardised systems for design and construction information	All firms using reliable standards for integration of design information into model
Bovis Lend Lease Pharmaceutical	Pharmaceutical, biotechnological and health care design and consultancy	Need to coordinate complex areas; upstream 3D use (not services)	Lack of standard software for whole construction process; not extensively using on site yet
Laing	Construction Contractors	Cost; needed to explore methods to increase profit margins	Difficulty in gaining relevant information from designers to construction model

RESEARCH ANALYSIS

The Viability of 3D CAD:

One of the reasons for undertaking this research was to see whether IT, in the shape of 3D CAD technologies, could provide or stimulate techniques to allow inter-organisational communication and coordination to be improved, and to resolve problems of gaps between design and contracting elements of construction work, and improve the amount of and access to, specific construction design information throughout construction work. The research findings suggest a partial and tentative yes. All of the organisations involved in the research were committed to making 3D CAD work; it is seen to build on existing IT use in construction design (i.e. 2D CAD)[4] and increase functionality to produce demonstrable benefits in terms of cost, and ease given the increasing complexity of construction work. Adopters have a vision of the future where 3D CAD has an even more important role, as the centre for coordinating design, construction and operation and maintenance (O&M) of a building; the 3D CAD model is thought to make a more usable and detailed O&M tool that any number of 2D schematic diagrams. AMEC and Bovis both thought that the lack of standardised ways of producing commensurable design information was one of the main inhibitors of this vision.

However, although a strong case can be presented for the benefits and likelihood of success for 3D CAD problems, not least of all through quoting the 10% of total cost Laing estimate they can and do save, the adopters are experiencing problems with trying to embed the technology into existing, everyday practices. Because of the different locations of 3D CAD, problems with the same technology varied widely, most ably highlighted through comparing Laing's problem of getting the information required from designers, and Arup's opposite concern of how to make contractors utilise the 3D information they as designers provide. It can be argued, though, that all of these difficulties are derived from the same source, which is the way the technology interfaces with the construction processes of which CAD and construction design form a part, compared with other actors expectations of how it will fit into these processes.

The problems of mobilising the necessary types of information, either from upstream to produce the 3D model, or downstream to ensure that it is used during on-site construction, are related to expectations and understandings about the sequence in which construction practices should take place, and established divisions of labour and expertise in various locations throughout construction work, crucially not just within the organisation adopting the technology or the individuals using it. One CAD designer estimated that when using 2D plans, about one fifth of the information required to build on-site goes into drawing the plan, four fifths therefore being added downstream. However, 3D CAD was estimated as requiring around three fifths before it can be produced. So two fifths of the total information required to construct a building has to be moved from downstream of the CAD department to upstream. The consequences of attempting to do this are being seen as a reluctance to provide necessary information; individuals are used to providing certain types of information (plans and paper based lists of quantities and components) in certain formats (printouts on paper) and do not expect to have to provide the computer CAD files, or have to begin themselves to work in 3D modes. They are used to performing specific practices which are at odds with the

[4] In fact, the route from 2D to 3D even uses consistent products; AutoCAD, one of the main 2D CAD packages is the main drawing software used in 3D CAD of all of the participating companies, and provides the basis for a suite of products for 3D CAD modelling and viewing.

informational requirements of 3D CAD use. Also, the individuals and organisations who produce some of the information required to build the 3D model may not even be mobilised on a project at the design stage. For example many specialist contractors do not get involved in a particular project until part way through on-site phases, so the information required by the CAD users is not just difficult to get; it may not yet have even been produced. This sequential mobilisation of skills in construction, resulting in a lack of specialist knowledge during design phases is a recognised problem, and has been the subject of some discussion[5].

The tensions between ways that the technologies necessarily work, and existing expectations and practices are not just confined to design information. The use of 3D CAD introduces new skills at certain locations, and de-skills certain areas of on site construction work. As well as craft-based skills the on-site builder also converts 2D drawings into 3D objects; in this case the (part of) the building itself. However, if 3D CAD is used, CAD users, not on-site construction workers, are doing the coordination of 3D objects, and are doing inside virtual space, not on the building site. The on-site practice is then reduced to assembly following detailed instructions using craft skills only, as the 3D model must be replicated faithfully on the building site. There is apparently no room for interpretation, discretion or problem solving, which is an integral part of creating 3D objects from 2D schematics. This results in the generation of tension between the 3D CAD adopting organisation who require certain types of downstream construction practice to follow the model during construction, and the organisations and individuals used to practices involving 2D drawings and extensive discretion.

Criteria Influencing New Technology Adoption:

These problems of de- and re-skilling have to be resolved before the view 3D CAD adopters subscribe to can be realised, for it to be considered as an acceptable solution to specific problems of the lack of information and communication. This research also highlights something that all technological innovation has in common; that the process is not as simple as 'plugging in' the technology, or making sure immediate users or operators are trained to a sufficient level of proficiency. The particular technology examined here has far reaching consequences, and requires adaptation of many different practices, and a reconfiguration of expectations and existing divisions of labour and expertise before it can be seen as integrated into everyday construction practice. As a development of examining these different accounts of implementation and problems experienced, several vantage points can be suggested as potentially of value to consider when adopting new technologies. These are outlined in table 2, and fig. 1 demonstrates how these factors all interact and effect the contest over the potential outcomes of attempts to adopt technology.

[5] see eg Vrijhoef & Koskella 2000 and Barlow, 2000

These dimensions could form a basic set of ideas to consider when the adoption of any new technology is considered. If the range or potential effects of the technology extend outside of the sphere of influence of the adopting organisation, it may introduce difficulties in getting other organisations to adapt to it. Similarly, if there are powerful stakeholders in the continuation of existing practices, it may be difficult to introduce a new technology requiring re-training or the redundancy of particular skills. If the expectation of a technology is very different to the reality of its use in a particular context or for a specific purpose, it may affect levels of support for or commitment to it.

Table 2. Criteria involved in introducing new technologies

Criteria to Consider	**Further Explanation**	**Example from research**
Requirements of the technology	Need for new or relocation of skills, need for new types or amounts of information	3D CAD requires new spatial coordination skills and more specific information
Reach / Scope of the technology	Extent over which technology and associated practices can cause an effect or influence	3D CAD not only affects practices of adopting CAD department, but tries to reconfigure upstream and downstream connections
Stakeholders in success of technology	Actors that stand to benefit from adoption of technology	Contractor's 3D Cad departments (i.e. Laing), client through reduction of costly alterations due to unforeseen problems, individuals / department that finance adoption of technology
Existing practices	Specific divisions of labour, distributions of expertise, routinised ways of working	Reluctance to provide more than 2D and generic information from upstream Difficulties in getting 3D model to be used on-site
Location of technology implementation	Understanding of where the technology fits into existing sequences, routines and orders of work	3D CAD sits in different places within wider construction work, depending on adopting organisation. Is always upstream from on-site phases

Expectations about the technology	Assumptions about how technology will work, how it will fit into work patterns, how it will change existing practices	3D CAD is thought to be an extension of 2D CAD; located in the same place and 'improving' 2D CAD's functionality and role in wider practices
Stakeholders in continuation of existing practices	Actors that benefit from continuation of current conditions	3D CAD can be seen as deskilling elements of on-site work, so may be resisted by those it threatens

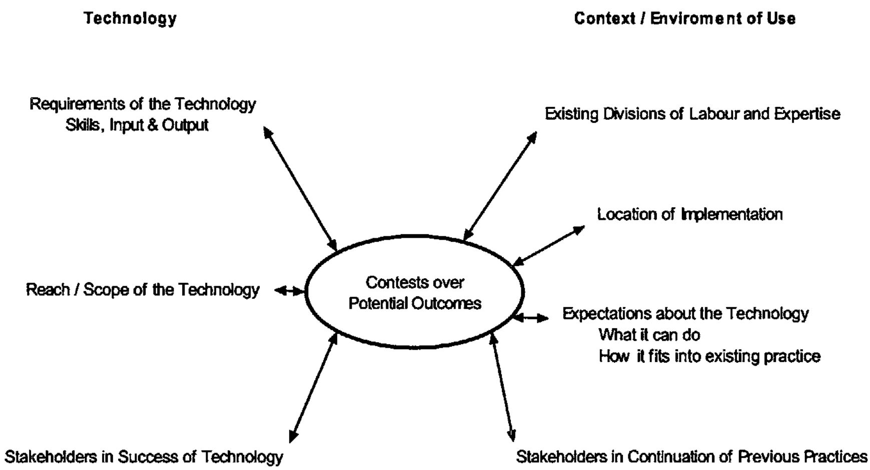

Figure 1 Factors to consider when assessing processes of new technology adoption

THE EXAMPLE OF 2D CAD ADOPTION:

An interesting way to test the usefulness of these criteria in the context of this research is to use them to look at the adoption and development of 2D CAD, which not only became a ubiquitous standard in construction design, but is also the bedrock on which much of the development of strategy to use, and expectation about, 3D CAD, is based. The early 1980s saw the start of large-scale take-up in CAD technology within construction design; AutoCAD, the most widely used CAD package, was first released in 1982, and by 1986 had sold 50,000 copies and released entry-level CAD products to act as an inexpensive way to try out as well as learn to use their software. The following year a London Institute City and Guilds certificate, a standard professional qualification in many areas of construction, in AutoCAD use was launched. Helped by many factors, including the actual benefits of CAD for construction designers, AutoCAD's own management of its product including continual upgrading and specialist training courses, the continual fall in price and increase in performance of IT hardware and product specific qualifications like the City and Guilds in AutoCAD use, enough momentum was created behind the application to make it a standard package to use in construction CAD, but also to make CAD use an accepted part of everyday construction practice.

COMPARING 2D AND 3D CAD:

Although this march to spiralling success can be viewed as a congruence of many mutually-enforcing trends (hardware price, good marketing, a perceived need for better 2D drafting tools in construction design and so on) it can also be seen differently. The requirements of 2D CAD involved new skills to operate the software, but crucially 2D CAD retained compatibility with existing practices in terms of requiring similar amounts and types of information to be input into a drawing, and producing a similar output to that expected – a 2D drawing on paper. No relocation of skills was particularly required; the rest of the actors involved in construction work would be unaffected whether drawings were produced with pen and drawing board or with CAD tools. The reach of this innovation didn't extend beyond the confined location of the adopting organisation; it interfaced with other construction practices in the same way that design using traditional technologies (i.e. pen and ink) did. Another crucial point regards what was expected from the new technology; it was expected to be a time saving product that produced high quality drawings. Alterations to designs that would have meant redrawing from scratch on paper would only mean amendments on the electronic version, and a new set of printouts. Because of the compatibilities with existing ways of working the real technology was closely aligned to expectation, and consequently there were no powerful stakeholders in the continuation of pen and paper methods beyond the actual designers and drafters themselves, within particular companies. Although it offered new and attractive tools for draftspersons and designers to use, in terms of overall construction practices of which drafting was a part, 2D CAD had little impact.

This allowed 2D CAD to be adopted on an organisation-by-organisation basis; it had few outside repercussions whether designers moved from paper to CAD. 2D CAD was able to gain such a wide following because it could be adopted for its intrinsic benefits and was already aligned with existing work practices outside of its immediate location, and so caused few problems. In terms of work organisation this makes 2D CAD a very different type of technological innovation that 3D, even though technologically they are very close. Support for these ideas can come from another look at CAD history, which tells us that even in the 1950s, when computers and graphical interfaces were at their most basic, 2D and 3D representations were concurrently being developed. AutoCAD has supported some form of 3D modelling since the late 1980s. One of the first CAD applications written for the Macintosh computer in 1984 was entirely 3D based. However, it is 2D CAD drafting that has made its mark on construction design; 3D technology has been around for as long as 2D, but has only recently begun to be considered a useful tool for construction design. It is plausible to suggest that 2D CAD was adopted because it create little disturbance in wider construction practices; it was up to designers and design organisations to decide to adopt or not without resistances or complications from outside. 2D CAD lived up to expectations and realised the promised benefits of quick redrafting and good quality output without troubling the upstream and downstream connections within which it was located. 3D CAD has much wider ranging implications than 2D, and it is perhaps only the complexities and low margins of contemporary construction work that has caused a resurgence of interest in 3D CAD as a viable tool.

This draws attention to the need for clear ways of distinguishing between different modes of new technology adoption; 3D technology has developed from (or even alongside) 2D CAD, but when thinking through the criteria listed in table 2. in implementation and use they represent very different propositions. 2D CAD was a tool for designers to produce and alter drawings quickly while maintaining good quality output; 3D CAD does this, but also challenges and changes the problems being experienced within construction work for which the reliance on 2D plans rather than more complete information, is a contributing factor. As such, it is a technology that changes the way construction design information is produced, made available, transferred and used, rather than a more time efficient replacement for an existing technology.

Examining aspects of new technologies like scope and up and downstream requirements also suggests that the sphere of influence of a new technology is important. The changes 2D CAD brought with it were more or less confined to the locations where it was adopted, and hence remained under the sphere of influence of the adopting organisation. It became a standard technological tool in construction design through convention; as more and more design organisations adopted it, it became accepted as a normal everyday technology; its use is now normal practice. By contrast, 3D CAD affects the sequences and divisions of labour and routines through which a lot of construction work is undertaken; not just within design organisations but also by contractors, specialists and consultants. The wider a new technology casts its net, the more potential resistances and tensions can arise. This is also connected to the idea of stakeholders; the more reactionary stakeholders exist, the more difficult adoption and acceptance may be. 3D CAD cannot be accepted as a standard in the same way that 2D CAD was; it cannot quietly slot into construction practices until one day it has become a requisite technology and set of competencies. As we've seen specific instances of its adoption create specific tensions between the technology, and expectation about how construction design should be produced, transmitted and used.

CONCLUSIONS:

3D CAD technologies promise to transform the way design information is produced and utilised in construction, easing problems of coordination and collaboration. The 3D CAD users studied in this paper suggest that this technology could potentially live up to expectations; those who have adopted it are realising benefits and are committed to continuing to incorporate 3D CAD into their work practices. However, challenges are evident; the reconfiguration of inter-organisational relations and information transfer is no small feat, and the adopters of 3D technologies are only one piece of the overall jigsaw that these technologies effect. The repercussions of using 3D CAD as a standard way of designing and 'virtual building' are extensive, and adopters are having to think of ways to ensure that their new requirement for upstream provision and downstream utilisation of 3D CAD models are fulfilled, but these areas are often outside of the adopter's sphere of direct influence.

Building on the story of 3D CAD, this paper offers a series of issues to consider when examining the possible implications of any new technology. Issues such as the location of the technology compared to the range of its possible implications, contests between different stakeholders, expectations about what the new technology will do and how it will do it and the requirements of the technology compared to existing or previous ways of working can indicate the potential ease or difficulty with which the technology can be implemented. These factors can help explain why 2D CAD was able to become part of everyday construction practice, and why 3D CAD presents a different set of challenges before it can be considered as having the ability to become a new standard way of producing, coordinating an transferring design information.

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Theme 2:
Globalization & Competitiveness

Issues for the Globalization of the Construction Industry

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ABSTRACT

This paper will examine these issues in the context of the limited knowledge of the specific implications regarding globalization and the construction industry. The paper will take the view that much of current knowledge of globalization and the construction industry is oversimplified with little consensus on the subject with respect to quantification and evidence.

INTRODUCTION

There are many issues in regard to the impact of globalization on the construction industry that have emerged or are still emerging. For example, the polarisation of the global economy; the new rules and regulations controlled by organisations such as the WTO; the influence of globalization on construction industry development; the listing of construction companies on stock exchanges; transparency of capital flows; the influence of shareholders on the strategic directions of the organisation and the impact of globalization on other, non listed, construction related businesses.

DEFINING GLOBALIZATION

The word 'global' may be over 400 years old (OED 2000 s.v. global). However the common usage of words such as globalization and globalize did not begin until the late 1950's. Since the end of the Cold War in the late 1980's, the concept of globalization has become more widespread. Today globalization is widely assumed to be crucially important

Generally, the concept of globalization is defined as (e.g. Friedman 2000, Scholte 2000, Mulgan 1999, Waters 1995) an international system of increasing connectivity between countries, corporations and individuals which involves some form of trade, exchange, sharing or distribution of either quantifiable or non quantifiable components (Najjar *et al.* 2000).

"A social process in which the constraints of geography on social and cultural arrangements recede and in which people become increasingly aware that they are receding" (Waters 1995: 3).

From an economic perspective globalization represents increasing capital flows and trade of goods and services and the spread of free-market capitalism to virtually every country in the world. From a social perspective globalization represents the sharing and exchange of ideas, beliefs and values as well as issues such as human rights, working conditions and consumer protection. From a legal perspective globalization represents rules and regulations of organisations such as the World Trade Organisation (WTO). From a political perspective globalization represents the international relations and multi trade agreements and trade barriers between individual countries and economic communities.

THE GLOBAL DEBATE

The global debate (Schwartz, 2000) seems polarised between those who say that globalization represents a new force that will change all society in a uniform way and those that say that globalization is nothing new and incapable of influencing the power of local states.

The problems associated with globalization include the inequitable distribution of goods, services and wealth together with the unresolved problems of human rights and an increased spread of poverty and disease. The main benefits of globalization are that it provides the opportunity for economic development and higher standards of living through wealth and technology transfer (Najjar *et al.* 2000).

Social commentators (e.g. Chomsky, Nader, Galbraith *et al.*) strongly criticise organisations such as the WTO the International Monetary Fund (IMF) the World Bank for being non transparent organisations, that conduct their business behind closed doors with no mechanism for public input and influence. They believe that the rules and multilateral trade agreements of the WTO do not encompass the fundamental values of society and are not accountable for key global issues such as the environment and human rights. They believe that the multinational 'corporate model' induces an enormous dependency on an export concentrated market and transforms more of the commonwealth of the world's natural resources, into patent monopolies e.g. the biotechnology issue (Najjar *et al.* 2000).

"The answer to the problems of world trade is to tear down the WTO and tear up the rules" (Nader *et al.* 1999, pg 3).

Advocates of globalization argue that free trade creates significant and meaningful job growth, increases the standard of living and fosters peace as a result of new found prosperity. They consider that ordinance of the WTO, the IMF and the World Bank, should be increased because, not only do they increase global trade but, also protect the interests of small companies because they can't afford lawyers and representatives abroad to take care of their interests.

"If global corporations and big business are the enemy, ... who will supply the jobs after they're gone?" (Nader *et al.* 1999, pg 13).

QUANTIFYING GLOBALIZATION

In terms of capital flows there are approximately US$ 1.7 trillion daily being transferred in the global market place. The majority of this flow, approximately 95%, is, unproductive, speculative flow, with about 80% of this having a return time of less than a week, much of this less than a day. The US$1.7 trillion a day represents over twice the combined total foreign exchange reserves of all countries. The majority of the risk associated with this speculative flow is taken by the people and Governments of smaller developing economies unable to absorb the impact of relatively large shifts of capital (Fortune, 2000).

The worst case scenario of unencumbered global capital flows for smaller and developing economies, is a collapse of local financial markets and subsequent economic recession, e.g. the Asian crisis of 1997, where there is a transfer of wealth from the public to the private sector and the majority of individuals of the country take the risk and pay the cost (Najjar *et al.* 1999).

Globalization has also seen an increasing tendency for polarisation and influence of large corporations. The world's top two hundred corporations, now account for about quarter of all global economic activity and employ less than 1 % of the workforce (Chomsky, 1999). The trend is for a fewer number of large corporations, accounting for an increasing proportion of economic activity, employing a decreasing proportion of workers and producing increasingly homogenous products. At the other end of the spectrum the trend is for an increasing number of smaller companies, employing an increasing proportion of workers, accounting for a decreasing proportion of economic activity and producing an increasing variety of services (Najjar *et al.* 2000).

Technologically speaking, the previous era of globalization was built around falling transportation costs resulting from the invention of the steamship, railroad and automobile. Today's era of globalization is built around falling telecommunications costs resulting from the development of the microchip, fibre optics satellites and the internet.

THE CONSTRUCTION INDUSTRY AND GLOBALIZATION

We currently understand as much about how the globalization system is impacting on the construction industry as we understood about the impact of ecologically sustainable development 20 years ago. Construction related commentators, to date, have discussed some general issues in relation to globalization (e.g. Weddikkara *et al.* 2001, Ofori 2000, Raftery *et al.* 1998, Miles 1991).

The theme of most of these commentators is to focus on the 'internationalization' of construction, in particular construction industries of developing countries, with the discussion directed at how a specific developing country or group of developing countries is reacting and/or is responding to the influence of large multinational construction organisations operating within their industries and how the multinational construction organisations are restructuring their processes and or adopting new processes in order to operate 'successfully' in these foreign industries.

Raftery *et al.* (1998) investigate several Asian construction industries and argue that the main trends resulting from globalization are: larger private sector participation in infrastructure projects; increasing vertical integration in the packaging of construction projects; and increased foreign participation in domestic construction. They argue that these trends are helping to polarize the technical, managerial and financial superiority of developed countries and that the developing countries will have to 'leapfrog' this gap in order to minimize their increasing inferiority. They consider that, in the long term, technology transfer, for example via joint ventures with developed countries such as those in the construction industries of Japan and China, may fill this gap

Ofori (2000) is critical of the 'general and abstract level' of some of the issues raised by Raftery *et al.* He argues that the effects of globalization may be illustrated when analysed through construction industry development and its component factors such as development of: materials; project documentation and procedures; human resources; technology; contractors and institutions. He also considers that these factors may be used to provide measurable indicators of how globalization impacts on the 'capacity and effectiveness' of the construction industries ability to meet the demands placed on it. There are those, however, that would argue that, in comparison to other industries, development of construction industry processes, products and services has been limited. and that although mankind has experienced more economic development in the past 20 years than it has in the previous 2000 construction industry development (CID), as defined by Ofori et al (2000), has been limited.

The successful businesses organisations operating in the global economy today that have not undergone significant development are the exception rather than the rule. Moreover, a large number of the worlds leading organisations operating today did not even exist 20 years ago e.g. Microsoft, Oracle etc, and chances are that they will need continued development if they want to be operating successfully in another 20 years.

A survey of international construction organisations would probably reveal that the major development in their procedures and processes of production and services provided over the past 20 years include, but not limited to, the following:

1. Implementation of information technology resulting in a move from manual to computerised, design, estimating, scheduling and project management procedures.

2. A shift from lump sum open tendering to selective design and construct procurement and competitive fee negotiation including partnering.

3. Operating with increasingly complex conditions of contract and pre-qualification requirements.

4. Implementation of collaborative industry reform strategies for industry improvement e.g. Egan Report, UK and CIDA, Australia.

5. Introduction of international standards for the implementation of factors such as quality assurance and information technology.

6. Increasing vertically integrated services.

7. Increasing implementation of concepts such as constructability, strategic alliances, best practice and TQM.

8. Diversification into non-traditional services and broadening of existing services e.g. facilities management.

9. Increasing foreign participation.

10. Increasing foreign ownership structure.

Of these developments perhaps the most significant has been the general implementation of information technology. It would be fair to say that the majority of this information technology is generic and was developed outside of the construction industry. Generally, a large proportion of research and development has been funded by the public sector of developed countries before being privatised and implemented in other industries. These predominantly tax payer funded initiatives result in a shift of economic growth and subsequent profit from the public to the private sector. It may be further argued that there has been limited technological innovation developed specifically by the construction industry, moreover there has been even less technological innovation developed by the construction industry that has been adopted by other industries.

One may argue a number of possible explanations why CID has been limited, including: satisfaction with the current situation; no demand for different or new products or services; a perception that changing business processes will not result in creating greater efficiency; unawareness of what areas to develop and limited time, resources and ability for implementing research and development. Furthermore, one of the biggest obstacles to construction industry development is that most construction organisations are run by managers who were, traditionally, trained as engineers, builders, and technicians not entrepreneurs, managers or businessmen. Their training involved the development strong analytical and problem solving foundations and a focus on the time, cost and quality issues of a project. These qualities do not create a mind set directed to the creativity and innovation required for research and business development.

Not withstanding the argument that the degree of CID is relatively minor, attempting to quantify the contribution of these developments in improving the overall capacity and effectiveness of the construction industry is, to say the least, difficult. Even more difficult is determining the degree to which globalization, if any, is responsible for these developments. Thus, raising the question of weather globalization does indeed influence construction industry development'?

If their is limited correlation between CID and globalization then what is the real meaning of globalization for the construction industry? Perhaps it is in the understanding of what constitutes a 'globally' successful business rather than simply the concept of operating in foreign markets; producing new products for new markets; or improving capacity and effectiveness of individual industries. Another view by which construction organisations may be considered as global is to consider their ownership structure (Najjar *et al.* 2000).

Not only are construction organisations shifting their operations into foreign industries, they are also being globalized via capital markets which facilitate shifting ownership structures. For example in Australia there is an increasing trend for foreign ownership of Australian construction companies. Australia's largest construction organisation Leighton Holdings is 47% owned by Hochtief Ltd (German). All other, publicly listed, construction organisations have some degree of foreign ownership with the total foreign ownership of major Australian construction organisations, in terms of market capitalisation, at approximately 30% (Najjar *et al.* 2000).

Similar trends are displayed in the construction industries of most developed economies where, generally, foreign owners consider developed economies as relatively safe investment opportunities resulting from relatively stable economies and transparent legal and political systems. The advantage to the foreign investor is the potential for optimising economies of operation, expanding markets and the possibility for technology and knowledge transfer. These possibilities would not be as transparent for the construction industries of developing countries.

The potential problems of the increasing foreign ownership of construction organisations is in a shifting away from the power of choice and control of individual construction companies and individual employees as shareholder accountability and the influence of parent companies on strategic direction increases. The increasing trend for foreign ownership will also impact the way construction companies do business and will impact on other construction related businesses. Furthermore, since construction industries are the most influential sectors of most developed economies, the unencumbered and non-transparent capital flows resulting from foreign ownership lends itself to potential instability of national economies.

GLOBALIZATION AND SPECIALIST SERVICES

In addition to construction contractors, their is the question of 'what is the impact of globalization on other construction related businesses? Is there an opportunity for small consulting businesses to, follow their construction company cousins into the global market place? Or, does the process of globalization mean something else?

There are those that would argue that large construction corporations are simply to big and slow to provide specialist services and that globalization creates niche market opportunities for specialist small businesses. Small businesses have the appropriate scale that allows flexibility, creativity, invention and the implementation of new ideas and innovations to occur effectively and rapidly. Others would argue that the specialist services are becoming vertically integrated into the overall product of single multinational construction organisations and that small businesses do not have the economies of scale, partnering opportunities and brand power to operate effectively in the global market place.

CONCLUSION

Globalization for the construction industry and construction organisations is encompassed in the social, economic, political and legal forces, resulting from of increasing global connectivity, which impact on the capacity, efficiency and effectiveness of the; i) processes of production; ii) products and services; and iii) ownership structure; of construction organisations.

The challenge for construction organisations operating in the global economy is to move towards a balance between their ability to recognise and move into foreign markets and market their existing services with their ability to optimise the business scale, processes, technology transfer and culture so that they result in organisations that are more efficient, meaningful and ultimately sustainable.

The challenge for the global construction industry is in minimising the polarisation and dehumanisation consequences of globalization and the corporate culture process. There is an opportunity for industry organisations such as the CIB to provide the 'corporate' direction and strategy for construction organisations to achieve the qualities that create real meaning in the organisation and contribute to the transfer of resources to developing construction industries.

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Managing A Firm's Competitiveness in Global Capital Investment Markets

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INTRODUCTION

This paper highlights the theoretical outcome of the research program "Improving the international competitiveness of firms belonging to Finland's capital investment cluster". The program was conducted by the team of Construction Economics and Management at the Helsinki University of Technology (HUT/CEM) and financed by the National Technology Agency of Finland, Tekes, during the years 1996-2000 (e.g. Huovinen 2000b, 2001, 2002b).

The context is businesses based on and firms operating in global capital investment markets. The capital investment markets deal with design, implementation, services, and life-cycle aspects of investments in the utilization of natural resources, energy supply, telecommunications, transportation, other infrastructure, manufacturing, and general building concerns. The generic scope of a capital investment includes feasibility studies, engineering and design, supply of a "production" line with installations and start-up, construction of buildings and infrastructure as well as after-investment services. Particular investment needs, project types, and contract scopes vary markedly within this generic scope.

The aim is to introduce a generic framework for managing a firm's competitiveness in order to succeed in the targeted competitive arenas of global capital investment markets. The framework consists of the three parts. The content is designed to enable management of globally operating firms to find answers to the three crucial questions, respectively:

(1) How can management foresee and gain foreknowledge of the conditions for future business success in the targeted global competitive arenas?

(2) How can management conduct the firm's global business(es) and operations more effectively than their competitors in the targeted competitive arenas?

(3) How can management be farseeing and attain those future states of the firm's global competitiveness that it perceives as essential in order to attain the firm's global business objectives in the longer term?

The design of the suggested framework is based on a synthesis of both the theoretical and empirical bases. The broad theoretical bases lie in the six research streams within strategic management, i.e. in the Porterian frameworks (Porter 1980, 1986, 2001), the resource-based view (e.g. Oliver 1997), competence-based frameworks (e.g. Hamel and Prahalad 1994), knowledge-based models (e.g. von Krogh et. al. 2000), change and evolutionary frameworks (e.g. Brown and Eisenhardt 1998), and frameworks for managing a multinational firm and a global business (e.g. Doz et.al. 2001). The author has reviewed these streams in his working paper (Huovinen 2000a) and in his ongoing study (Huovinen 2002a).

The primary empirical context is related to a group of 15 firms based in Finland that are among the leading firms in the global capital investment markets. These firms are engaged in such global businesses as telecommunications network contracting (e.g. Networks Division of Nokia Corporation), pulp and paper mill contracting (e.g. Metso Oyj and Foster Wheeler Finland Oy), pulp and paper mill engineering & design (e.g. Jaakko Pöyry Oyj), power plant contracting (e.g. Wärtsilä Oyj), general building and infrastructure contracting (e.g. two Swedish-owned subsidiaries, Skanska Oy and NCC Finland Oy), and the supply of prefabricated concrete products (e.g. Addtek International Oy).

FORESEEING FUTURE COMPETITION IN GLOBAL CAPITAL INVEST-MENT MARKETS

It is assumed here that a firm's successful transition into the future depends upon the degree to which the causal thinking of its managers will coincide with future market developments. Thus, foresight and foreknowledge are two of the critical management competences. Foresight refers to a manager's tendency to spend significant amounts of time engaged in thought or care for the future. Foreknowledge relates to the predictions that top management (team) makes about the future (Mosakowski 1998).

How can management foresee and gain foreknowledge on the conditions for future business success in the targeted competitive arenas of global markcts? It is argued that management should understand and deal with the seven factors inherent in global capital investment markets as follows:

(1) Understanding the structural and dynamic forces in capital investment markets

(2) Anticipating the fluctuations of market volumes

(3) Understanding the different logic of the six global contracting businesses

(4) Mastering the procurement strategies used by the primary client groups

(5) Understanding the rules and boundaries of the five integrated competitive arenas

(6) Mastering the various international business operations

(7) Mastering the various international financing solutions.

Market dynamism involves both long-term development and short-term fluctuations. In the long-term, all economies develop through three main stages and thus any given economy belongs to the advanced industrialized (AICs), the newly industrialized (NICs), or the less developed countries (LDCs). Capital investment is intimately related to industrialization and urbanization. According to Bon (1992), an S-shaped process of urbanization is consistent with an inverted U-shaped profile of capital investments: both the share and volume of capital investments in the GNP first grow and then decline as the GNP per capita increases in any one country over time. Primary dynamic (driving) forces include technological and social changes related to capital investment markets across the globe.

Fluctuations of capital investment markets are associated with short-term business cycles and public economic developments. Recession inevitably occurs in any given market. It seems that management can better ensure the firm's profitability when its portfolios of businesses, investment sectors, core compe-tences and products, countries, and customer groups are in balance.

Core global businesses are contracting businesses because contractors typically take responsibility for the engineering, design, and implementation of capital investments up to their total values. Clients include versatile investors and developers that act as short and long-term owners of capital investments. Contracting businesses can be differentiated across investment sectors into six major groups, see Fig. 1.

Procurement strategies and methods (in the UK and EU contexts; contracting or delivery strategies and modes/systems in the US context) are levers that shape competition. Namely, the procurement method determines the number, contractual roles, and responsibilities between the investor, contractors, financiers, designers, and suppliers by capital project. Each investor applies the particular method that he believes will ensure the attainment of the best outcome in terms of his investment criteria such as functionality, buildability, quality, money, and time.

The five competitive arenas can be identified in capital investment markets across the globe (Fig. 2). Competition differs among these five arenas and may involve competitors that operate globally, regionally, and/or only locally. Arena 1 consists of ownership and use of systems, plants and utilities over their life-cycles as well as of trading their outputs. Typical competitor groups are owners, operators, output sellers and users as well as O & M service firms. Arena 2 includes capital investing, i.e. new, modernization, and renovation investments in various sectors. Primary competitor groups are investors (owners), developers, venture capitalists and other financiers.

Investors' procurement strategies and methods determine the existence of two other arenas. Arena 3 includes contracting of wholes, i.e. investors require contractors to take the total responsibility for the design and implementation of their capital investments. Primary competitor groups are system, general, turnkey, and design-to-build contractors as well as various CM firms.

Arena 4 includes the two primary client groups and the contracting of parts. Many investors are themselves capable of managing their capital investments. Thus, these investors first hand out one or several contracts for engineering and design, and later a set of subcontracts for carrying out all the construction and installation works at site. In turn, most aforementioned contractors first hand out engineering and design contracts (only a few contractors possess in-house competences for this) and a set of subcontractors for various works. Typical competitor groups are engineers and designers of various disciplines as well as plant, machinery, equipment, main, HEPAC, specialty, and trade contractors.

Arena 5 includes many client groups and the supply of various inputs that are needed for implementing capital investments. Client groups include investors, CM firms and all kinds of contractors that hand out a set of contracts for procuring the inputs needed within the technical scope of their own contracts. By definition, suppliers of inputs do not take responsibility for works at sites. Typical competing supplier groups are equipment, component, building product, and construction material suppliers.

Firm roles, contract types and relations as well as competence requirements differ in the five global competitive arenas. Arena boundaries are partly blurred and competition rules are revised. Typically, this is caused by globally leading contractors that operate across the arenas. For example, they may assume roles of investors and/or co-financiers in Arena 2, as well as that of service firms offering services to owners and operators over the life-cycles of systems, plants, and utilities in Arena 1.

International business operations are typically systems selling, project exports, subsidiaries, joint ventures and consortiums, partnerships, subcontracting, technology transfer, licensing, management contracts, and services contracts. Mastering the operation in question is one of the conditions for managing risks.

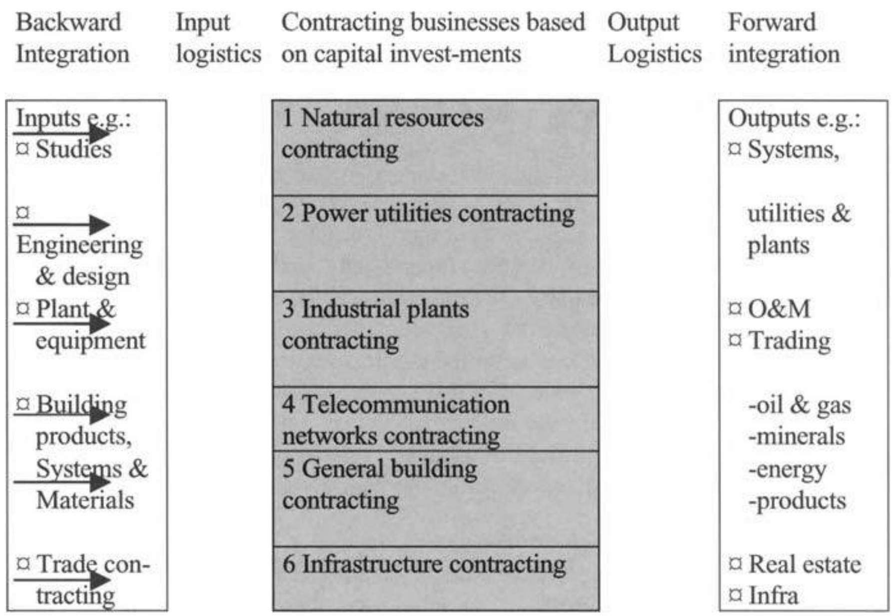
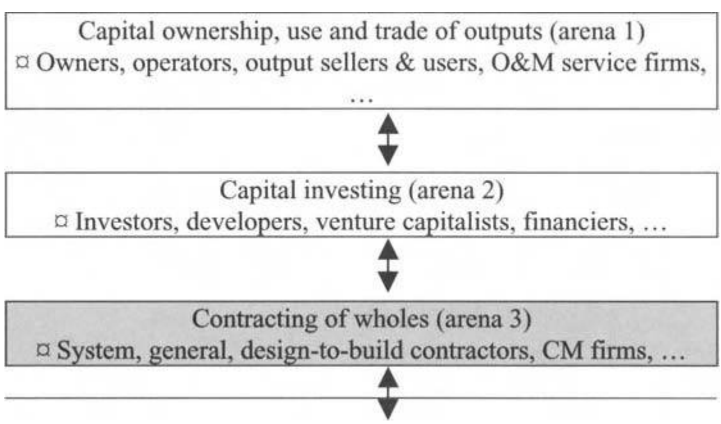


Figure 1 Core global contracting businesses with integration options. (Applying Huovinen 1996)



Contracting of parts (arena 4)
¤ Plant, engineering, trade & subcontractors, engineers, designers,...

↕

Supply of inputs (arena 5)
¤ Product, component & material suppliers, logistics firms, ...

Figure 2 Five competitive arenas in global capital investment markets. (Applying Porter 1980)

Financing propositions for capital investments play often a decisive role. An investor often requires that the contractor arranges the financing of the capital investment in question. A contractor may also assume the role of a minor shareholder for a limited period of say 3–10 years. In the AICs, the most recent solutions combine private and public financing sources. In the LDCs, the public investor has adopted various build-operate-transfer (BOT) strategies in order to enable the realization of major infrastructure projects.

MANAGING A FIRM AS A DYNAMIC GLOBAL SYSTEM

It is assumed here that a firm will attain its high global business objectives when its management designs and organizes it as a dynamic system that will serve as the single basis for managing both global business operations and competitiveness developments seamlessly and effectively. Thus, also system design is one of the critical management competences.

How can management conduct the firm's global business(es) and operations more effectively than competitors in the targeted competitive arenas? It is argued that management should design and manage the firm as a dynamic global system consisting of the five elements as follows (Fig. 3):

(1) Advancing contract -specific competitive strategies and offerings

(2) Integrating global, local and contract -specific business processes

(3) Nurturing core technologies, knowledge and competences

(4) Governing the flexible firm frame across the globe

(5) Extending the firm frame beyond its legal boundaries.

It is argued here that this kind of a dynamic system is needed for both managing a firm's global business performance and its competitiveness in an integrated, effective way across the globe.

Critical management tasks are inherent in each of the five systemic elements. First, the front-line element includes offering the best solutions to the targeted clients and managing the contracts to be won for high client satisfaction and high firm profitability. Second, the process element includes the management of a firm's business processes and contract tasks effectively as a dynamic matrix where teams play integrative roles. Third, the back-end element involves the management of core technologies, knowledge, and competences. Fourth, the frame element emphasizes top management's (and the primary owners') role and tasks that add value to a firm's business performance and shareholding. Finally, the extended frame element includes partnerships, networking, and similar new forms of long-term collaboration between various stakeholders.

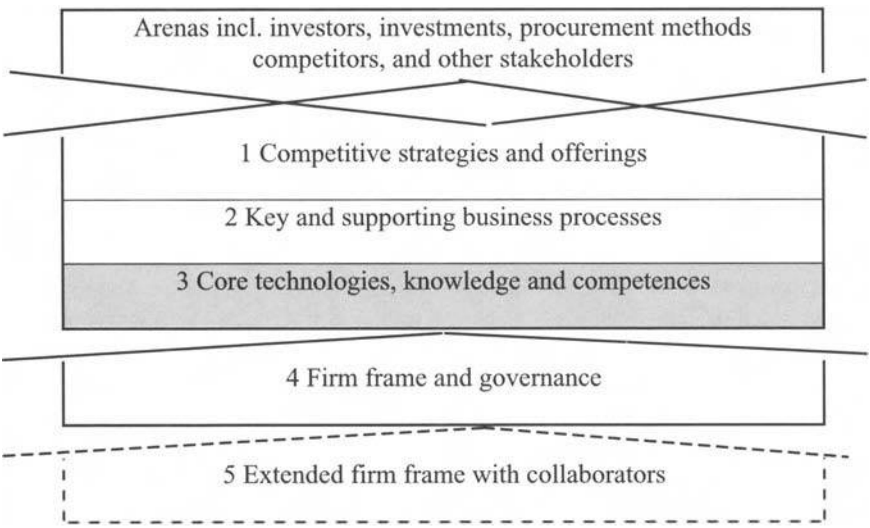


Figure 3 Designing and managing a firm as a dynamic global system (elements 1-5).

FARSEEING FUTURE STATES OF GLOBAL COMPETITIVENESS

It is assumed here that a firm will excel in global business when its management's preferences for the types, timing, and size of investments in competitiveness coincide with future success conditions in the targeted arenas. This far-sightedness is one of the critical management competences that reflects a manager's preference for long-term versus short-term pay-offs. It also reflects a manager's situation-independent traits and characteristics (Mosakowski 1998).

How can management be farseeing and move toward those future states of the firm's global competitiveness that it perceives as essential in order to attain the firm's global business objectives in the longer term (better than its competitors)? It is argued that management should apply the five development principles as follows:

(1) Understanding the en-/disabling roles of owners and (top) management

(2) Accepting the implicit limitations related to long-term development paths

(3) Focusing and setting targeted levels for the competitiveness development of the five systemic elements

(4) Determining global business and competitiveness profiles

(5) Driving with the causal relations between market foresight, business objectives setting and competitiveness farsightedness.

Owners and management are primary decision makers in firms. They are to both praise and blame (non-) sustainability of their firms. Here, this implies that any major development of a firm's global competitiveness should be started by a self-assessment and an anticipative education program of the decision makers themselves. The enhanced management competences then enable organizational and competitive developments within the firm in question (and vice versa).

A set of alternative long-term development paths is limited in terms of the starting and ending states of a firm, i.e. within the dynamic global system. Here, the current and future targeted competitive positions of a firm are emphasized. A high (low) starting position of a firm enables (disables) management to consider future business positions that are at higher levels and future competitiveness states that are stronger than the current ones. But it seems that radical leaps within a firm's global(ization) process such as "a born global" with a dominant position will be exceptions in the context of global capital investment markets.

Management chooses the focus and targeted levels for developing a firm's global competitiveness. Management can couple its client knowledge inquiry (and relationship creation) with competitive benchmarking in order to establish a viable frame of reference for choosing the right development targets and means. Thus, the primary clients, their procurement behavior, and the competitors' positions in each of the targeted competitive arenas should be adopted as the criteria for making those strategic choices. Here, the content design of a firm's competitiveness development program consists of the two subprocesses (Fig. 4).

The analysis process starts with gathering data on the targeted clients and anticipated competitors. This data is used for determining the success requirements, i.e. the best values possible for a firm's five elements as a dynamic global system. The synthesis process means choosing the focus and the targeted levels (within a range of the best and average ones) for each of the five elements.

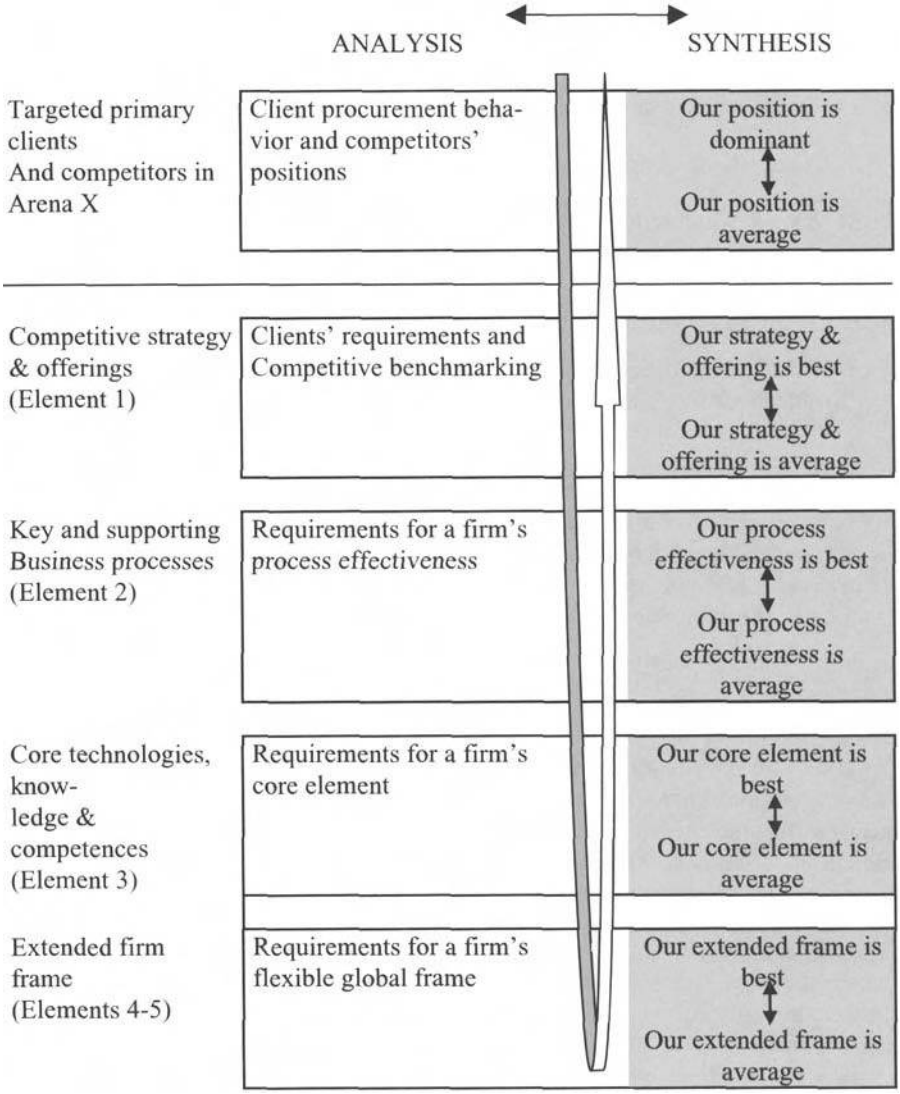


Figure 4 Primary clients and competitors as the basis for developing a firm's competitiveness.

In practice, the global competitiveness of a firm is tested and measured through a series of competitive (bidding) situations that result either in it winning targeted contracts or losing them. Management's attention is focused on direct competition, its competitive strategies and offerings (element 1). Here, it is argued that, in the future, managing a global business successfully implies that management must broaden its view on competitiveness to cover all the five systemic elements. Thus, management should determine a firm's global business and competitiveness profiles to reveal reliably the past and current states of the dynamic global system as well as to manage it toward the future targeted states. Balanced scorecards and similar approaches of late seem to be applicable for this kind of a continuous assessment process.

Finally, it is argued here that the successful management of a firm's global competitiveness implies driving with the causal relations between market foresight, business objectives setting and competitiveness farsightedness (Fig. 5). At the level of a firm's business(es), (i) the management should on the one hand anticipate future developments in the targeted competitive arenas and geographical markets. This market foresight is the best external, predictive information that is available for (ii) setting initial long-term objectives for a firm's global business(es). In turn, (iii) a set of long-term objectives for a firm's global competitiveness are deduced from those long-term business objectives. On the other hand, the past and current states of a firm's competitiveness enable and limit initially the setting of its future objectives for competitiveness.

The critical task of management is then to fit together the final long-term objectives of the global business with those of global competitiveness. Management may have to reset these two sets of the objectives many times during the time span in question, e.g. the years 2003-2005. Namely, causal relations imply that any major change in the targeted competitive arena, a firm's business performance, or its competitiveness will unbalance the states of the related systemic elements. Here, competitiveness farsightedness seems to be the most critical competence.

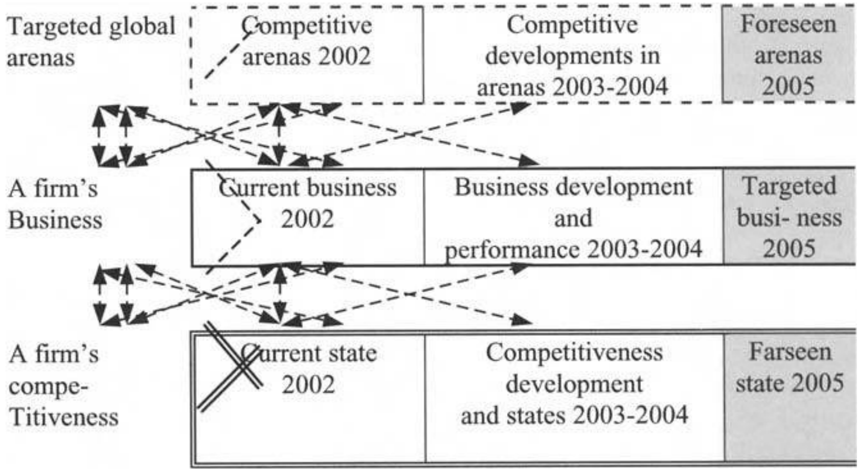


Figure 5 Causal relations among global arenas, a firm's business and its competitiveness.

CONCLUDING REMARKS

The population of firms operating in global capital investment markets belong to the six business scope groups, or sectors, differentiated in the ways each group typically leverages its adding value to design, implementation, and servicing of capital investments in their targeted competitive arenas (markets). It is argued that the suggested framework is applicable to the context of the six global business scope groups, namely to (i) technology-intensive contracting, (ii) technology-intensive design, and consulting, (iii) construction-related contracting, (iv) construction-related design and consulting, (v) the supply of building products, systems, and materials, and (vi) real estate ownership, development, management, and services. The actual uses must be preceded by a set of tests for identifying the generic and group specific factors to be included in the applied framework and for maintaining the theoretical validity with regard to each of the six business scope groups.

There are only a few similar theoretical frameworks for managing a firm's global business and/or competitiveness in the applied literature related to capital investments (see e.g. Abdul-Aziz 1991 and 1994, Betts and Ofori 1992, Hörschgen 1992, Bennet 1994, Moavenzadeh 1994, Flanagan 1994 and 2001, Venegas and Alarcon 1997, Chinowsky and Meredith 2000, Langford and Male 2001, De Haan et.al. 2002). This may be the case owing to the fact that both managers and researchers related to capital investment markets direct their attention primarily on how to manage effectively individual contracts, assignments, projects, deliveries, and services.

Finally, I would like to encourage scholars across the globe to design strategic management frameworks and apply them to the six business scope groups inherent in global capital investment markets. In practice, an interested scholar can first familiarize him-/herself with existing generic, industry or business specific frameworks in the strategic management literature. Overall, the most challenging and rewarding task is to introduce your new frameworks to firms, allowing them to be tested via critical discussions with practitioners. At the end of the day, practitioners will adopt only a few new frameworks that they perceive to make a difference.

In the US context, strategic management scholars (of Academy of Management) recently admitted that they have been less than successful in putting management knowledge into practice. They do not adequately understand the practice of management in two respects. First, they have not found adequate ways of putting research knowledge into practice. Second, they have not figured out how academics, consultants, and practitioners might co-produce management knowledge (Van de Ven 2000). I am convinced that there are optimistic and capable readers who perceive this poor state of implementation, and from whom efforts leading to personal opportunities will be initiated via the penetration of our applied field of strategic management and the linking of same with the practitioners within the firms.

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A METHOD FOR EVALUATING INTERNATIONAL CONSTRUCTION PROJECTS

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ABSTRACT

The evaluation and selection of construction projects in global markets has a significant impact on the future of international and global construction companies. Construction is a project based industry where the operations of an organization revolve around the present and future projects of the company. The projects which a company decides to pursue will impact the direction of the company, the resources the company needs, the risks it incurs, and the rewards it obtains.

An investigation into project evaluation decisions made by construction companies pursuing international projects found that companies rely heavily on intuition of the construction executives to select projects (Messner 1994). It also found that the decision process is unstructured which can cause a variation in decision quality.

To improve the project evaluation decision, the Project Evaluation Process Model (PEPM) was defined which decomposed the decision into five main subprocesses. Key questions are identified for each of the subprocesses. These subprocesses are:

1) *Assess project feasibility,*
2) *Determine ability to perform,*
3) *Assess competitive advantages,*
4) *Determine project risks, and*
5) *Select projects to pursue.*

To support this decision process, the Organization Based Information Architecture (OBIA) was developed. It identifies the factors and information that an executive must know to effectively evaluate an international project opportunity. The OBIA identifies five categories of information which are: organizations, commitments, processes, environments, and facilities. Each of these categories is decomposed to identify additional information needs. The application of the OBIA and PEPM is illustrated through the presentation of a case study.

BACKGROUND

Recent research efforts on the project evaluation decision have focused on the development of decision support and analysis tools to make the 'bid/no bid' decision and the bid mark-up decision. Several rule-based expert systems have been developed by Tavakoli and Utomo (1989) and Ahmad (1990) to assist in the decision process. Neural network systems have also been developed by Moselhi et al. (1993), Hegazy and Moselhi (1994), and Dias and Weerasinghe (1996). More recently, two decision support systems were developed by Chua et al. (2001) and Chua and Li (2000) which focused on the use of case-based reasoning and the Analytic Hierarchy Process (AHP) technique, respectively, to aid a decision maker. These previous research efforts did not attempt to define a comprehensive model for the analysis of the project evaluation decision. Instead, most of these efforts focused on the implementation of computer tools to assist in the decision process by providing quantitative data to the decision maker regarding the relative attractiveness of a project based on a specific list of risk factors.

The research presented in this paper approaches the decision process in a different manner. The research focuses on the development of a process model and information structure to support the decision maker in making consistent decisions. It does not provide a quantitative or decision support model for the evaluation of the project. Throughout the research efforts, it was noted that many project evaluation decisions are heavily impacted by two or three key factors. These factors must be analyzed to a great level of detail. This makes the quantitative representation and evaluation of the decision very challenging.

MODEL DEVELOPMENT AND TESTING

The models presented in this paper were developed from detailed interviews with ten executives from both United States domestic and international construction firms. A content analysis was created for each of the interviews to identify and organize the information provided to the researcher. The models were then tested through a detailed case study analysis of ten international project located on five continents. The OBIA was found to identify all important information needed to analyze each case study project. The PEPM assisted in the identification of the key issues that impacted the company's decision on each case study.

THE PROJECT EVALUATION PROCESS MODEL

To provide a more structured approach to the project evaluation process, the Project Evaluation Process Model (PEPM) was developed (see Figure 2). This model identifies the key decisions that must be made to effectively evaluate potential projects to pursue in international markets.

Table 1: Project Evaluation Process Model Questions

Assess Project Feasibility

- Can the owner / client finance the project?
- Is there a demand for the product / service which the owner is trying to produce?
- Is there a good probability that the facility will be constructed as planned?

Determine Ability to Perform

- Does the organization have the resources needed to perform the project?
- If not, can the organization obtain the needed resources?

Assess Competitive Advantages

- Who are the competitors?
- Does the organization have an advantage in the following areas relative to each competitor?
    - Technology
    - Management
    - Resources
    - Range of services
    - Relationship
    - Image
    - Location
    - Regulations
    - Timing

Determine Project Risks

- What risks exist in the following categories?
    - Various organizations involved
    - Commitments / contracts
    - Processes to be performed
    - Facility
    - Environment

Select Projects to Pursue

- Does the project fit within the organization's goals?
- Is it the most efficient use of the companies resources?
- Could the company develop a better organization to pursue the project?

Table 1 shows the key questions identified throughout the research that must be answered within each decision subprocess.

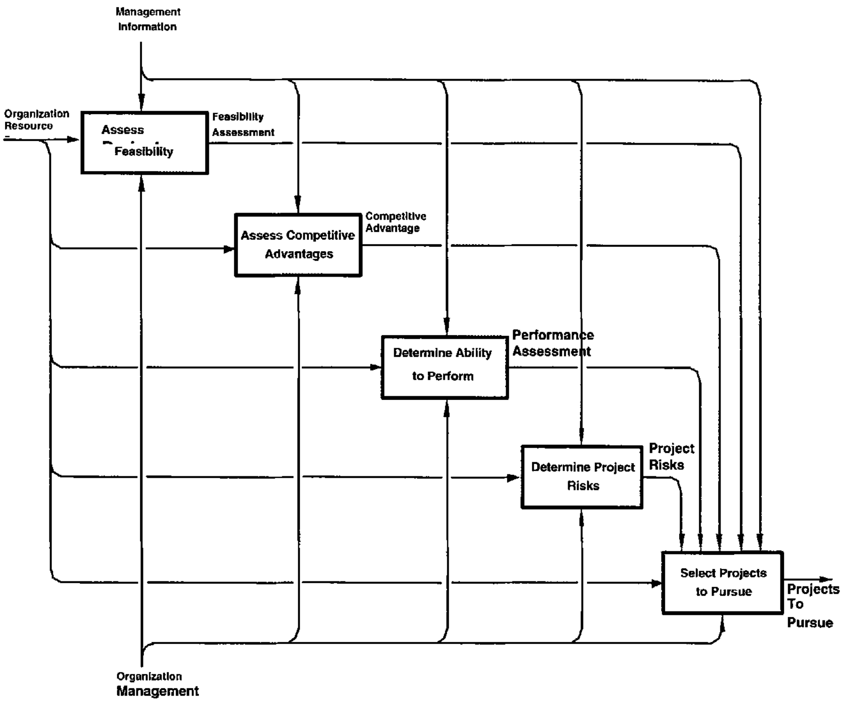

Figure 1: Projet Evaluation Process Model

One of the most important subprocesses when evaluating projects was the determination of the competitive advantages that a company has relative to other potential competitors. These competitive advantages were defined throughout the interview and case study analysis and are shown in Table 2. This table shows the number and type of advantage that the evaluating company had for each of the ten detailed case studies used to evaluate the model. Although no conclusions can be drawn from the limited number of case studies, it does appear that the relationship advantage is an extremely important advantage in international markets. Two of the competitive advantages were not noted on any of the case study projects, but they were defined through the initial model development interviews. Examples of these two competitive advantages were provided within the interviews.

Table 2: Case Study Competitive Advantages

Competitive Advantage	Cases										Total
	1	2	3	4	5	6	7	8	9	10	
Relationship Advantage	X	X		X	X	X	X		X	X	8
Technological Advantage							X	X	X	X	4
Managerial Advantage		X			X	X		X			4
Corporate Image Advantage	X	X			X						3
Location Advantage					X	X				X	3
Financial Resource Advantage	X			X							2
Range of Services Advantage	X					X					2
Timing Advantage		X					X				2
Physical Resource Advantage		X									1
Human Resource Advantage											0
Regulatory Advantage											0

THE OGANIZATION BASED INFORMATION MODEL

A large amount of project information must be obtained to support the project evaluation process defined in the PEPM. To assist in the organization of this information, the Organization Based Information Architecture (OBIA) was developed. The information is broken into the following five categories: Organization, Process, Product, Environment, and Commitment (see Figure 2). Detailed attributes of each category have been defined and are contained in Messner (1994).

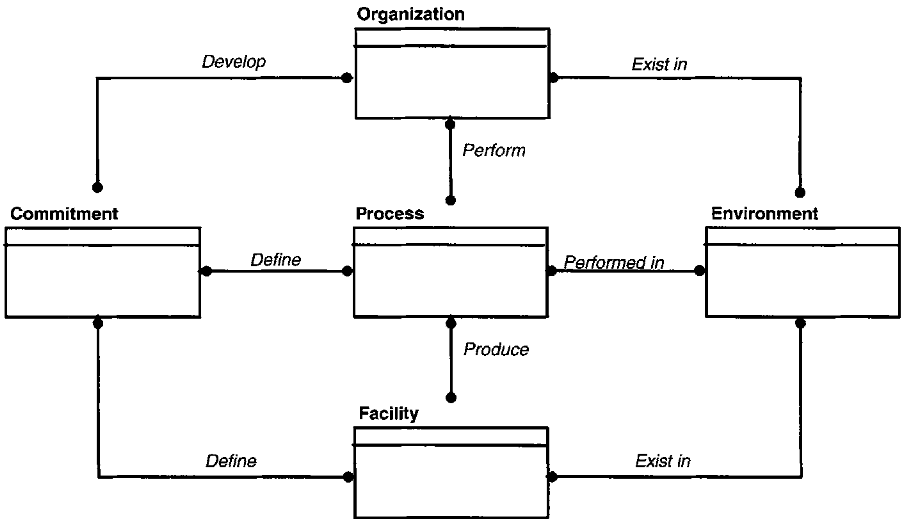

Figure 2: Organization Based Information Architecture (Level 0)

CASE STUDY ANALYSIS

To illustrate the application of the models, a review of one of the case study projects used to evaluate the models follows. The case study data was collected from an executive in a large EPC contracting company located in the United States. This particular case study focused heavily on the analysis of competitors since it was a competitively bid project. Other case study projects were more focused on particular relationships with different project players, specifically the owner or designer, and with the environment of the facility.

This case study example is a large power plant project located in Asia1. The company interviewed was approached by a large international trading house and asked if they were interested in developing a team to bid the lump sum, turnkey project. The particular bid that they would submit was for one of several different bid packages for the power plant project. It included the engineering, procurement and construction of several large pieces of equipment. Following the invitation by the trading house to bid this project, the EPC contractor performed an evaluation process where they considered a variety of information related to the project to determine whether or not to commit the resources to pursue and bid the project.

[1] Specific details related to the project and the companies involved are not provided for confidentiality reasons.

Case Study Information

Several different categories of information were considered when evaluating this project. The information which was discussed throughout the interview with the executive has been organized into the OBIA Categories. A detailed description of the process, product and environment are not presented as separate items in this paper. They impacted the project through the competitive advantages of the company and are referred to in the competitive advantage subprocess section.

Evaluating Organization:

The EPC contractor had never performed a lump sum, turnkey project in the international market and was not familiar with the environment in the Asian country. Therefore, the EPC contractor decided to develop a joint venture with another organization to perform the construction services portion of the contract. The initial joint venture partner pursued by this construction company declined the offer and stated that they would be bidding the project with a different engineering firm. The EPC contractor then identified a large European general contractor who was interested in performing the project. This general contractor had experience with international work (90% of their contracts were international) but had never worked in Asia. The contractor had a market goal to enter into the growing market in Asia. Therefore, they developed an agreement to form a joint venture. The final bidding group consisted of the trading house, the EPC contractor and the international general contractor. The information of specific significance in the decision to pursue the project was:

- •The EPC contractor had a goal to increase international activity,
- •The international general contractor had a goal to enter into the host country's market,
- •The international general contractor was capable of working effectively in Asia due to experience in other foreign countries,
- •The EPC contractor was very proficient at engineering the type of facility specified,
- •The trading house had a good relationship with the owner, and
- •The EPC contractor had a good relationship with the schematic designer.

Owner Organization:

The owner for the facility was a public utility controlled by the Asian country's government. This utility was responsible for managing the entire facility design and construction which was estimated at approximately US $800 million. The information of specific significance in deciding to pursue the project was:

- •The owner had previous good relations with the trading house,
- •The owner was receiving financing from the World Bank, which provided solid financial backing but also opened the project to international competition.

Competitor Organizations:

Several different competitors were considered when evaluating this project. Initially, fifteen companies obtained the bid documents for the project. It was almost impossible to determine which companies out of these fifteen companies would bid the project since several different equipment manufacturers could be used and the companies were from all different geographical locations. However, the EPC contractor was able to determine the three most serious competitors and a detailed consideration was given to these three competitors.

Competitor 1:

- •Competitor 1 was a large international EPC contractor with significant power experience,
- •Competitor 1 was previously inflexible to the owners needs on other projects, and
- •Competitor 1 was known for using standardized designs, which were not the type of design requested by the owner.

Competitor 2:

- •Competitor 2 was also a large international EPC contractor with significant power experience,
- •Competitor 2 had a poor relationship with the owner due to a past failed project, and
- •Competitor 2 was not experienced with specialized designs.

Competitor 3:

- •Competitor 3 was a large international EPC contractor with significant power experience,
- •Competitor 3 had obtained one of the other bid packages for the same project, and
- •Competitor 3 was very capable of developing a customized design for the project.

When considering the various competitors for the project, Competitor 3 was considered the most critical. They eventually did not pursue the project. This was also the competitor which was asked to joint venture with the EPC contractor to perform the contract. The information about the competitors was also used to develop the bidding strategy for the project. The evaluating organization attempted to expose the weaknesses of the other competitors when bidding the project.

Commitment Organization:

There were several commitments (or contracts) which influenced the decision to pursue the project. The most critical contract was the contract which the owner was proposing for the bid package. The following factors were considered:

- •The contract was a lump sum, turnkey contract.
- •The scope of services was defined through product specifications and these specifications were not specific to one equipment vendor. The capability to integrate the equipment through custom engineering was critical.
- •The payments were based on milestone dates and penalties would be imposed for not submitting information to the owner by these milestone dates.
- •The contract was written in English.
- •The payments were in US Dollars.

Case Study Project Evaluation Decision

The following describes the decision process followed by the evaluating organization within the context of the Project Evaluation Process Model.

Step 1: Assess Project Feasibility

There were few risks related to the project not being performed or the owner not being able to fund the project. Other portions of the project were already under construction and the funding for the project was through the World Bank, a very stable financial institution.

Step 2: Determine Ability to Perform

The EPC contractor was confident that they could perform the scope of services for completing the contract. They had experience in the domestic United States market with this type of engineering and construction and were capable of performing the same tasks for an international project, especially with the support of their joint venture partners.

Step 3: Assess Competitive Advantages

A large emphasis was placed on determining the different advantages which the evaluating organization had relative to the project. The following advantages were identified by the interview participant:

- •Technological advantage: The EPC contractor had more experience at designing specific connections between specialized equipment.
- •Relationship advantage: The EPC contractor had a good relationship with the conceptual designer and the international trading house had a good relationship with the owner.
- •Location advantage: The international trading house had experience in Asia and was very familiar with the local environment.

Step 4: Determine Project Risks

The following risks were identified as being most important on this particular project, from the EPC contractor's perspective:

- •Procuring the equipment for the budgeted cost,
- •Performing the engineering within the budgeted hours,
- •Getting equipment through customs on time and without unexpected costs, and
- •Obtaining payments in the times specified by the contract.

Step 5: Evaluation Decision

The project fit well within the goals of the company. The risks were not considered excessive, and the opportunity to gain entry into a new market was very important for the contractor. It was also important for the contractor to "keep their resume current". This would assist in procuring work in the future. Therefore, the contractor did decide to pursue this project and submit a bid for the work package.

Case Study Outcome

The joint venture between the United States EPC contractor, the European general contractor and the international trading house won the contract with the lowest cost bid with exceptions included. Competitor 1 had a higher price and the engineering design was not very detailed, as expected. Competitor 2 had many exceptions due to the inflexibility of the engineers, therefore there price was also higher. Competitor 3 decided not to bid the project.

Two years into the project, the equipment design is complete and 90% of the equipment has been procured at its budgeted cost or lower. The project is expected to be a success for the company.

CONCLUSIONS

This paper presents a model for providing structure to the project evaluation decision process to create a more systematic and informed evaluation of potential international projects.

The Organization Based Information Architecture assists in the identification of important information regarding the evaluation decision and provides a structure to this information. The Project Evaluation Process Model assists the decision maker by defining the most important questions to consider when evaluating a project.

This paper also identifies the types of competitive advantages on construction projects and provides insight into the importance of the various advantages. Although ten case studies can not provide definitive conclusions on the importance of different advantages, it appears that the relationship advantage is a very important advantage for contractors when evaluating international projects.

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Critical Success Factors in International Development Project Management

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ABSTRACT

International Development Project environment is far more complex than domestic projects in industrialized countries. The World Bank Group's data and other evidence suggest high incidents of challenged international development projects. There are many internal and external, visible and invisible factors that influence the environment and create a high amount of risk in accomplishing the project objectives. This paper elaborates a conceptual framework for international development project management and the characteristics of international development projects, which should be taken into consideration during the project initiation and project planning phases in order to enhance project success.

This paper also identifies the factors that cause completed or in progress international development projects to be challenged. The factors have been classified into ten categories based on their nature. These cover issues of political, legal, cultural, technical, managerial, economical, environmental, social, corruption, and physical. This paper describes these factors with a view to understand their nature from the perspective of the project managers who are required to manage international development projects.

INTRODUCTION

The international development project environment poses special problems for the project managers due to inherent characteristics. The World Bank Group's data (World Bank, 1999) and other evidence (Bastani, 1988, Beamish, 1993) suggest high incidents of challenged international development projects. This paper attempts to identify the factors that cause completed or in progress international development projects to be challenged. The factors have been classified into ten categories based on their nature. These cover issues of political, legal, cultural, technical, managerial, economical, environmental, social, corruption, and physical aspects.

This paper elaborates these factors with a view to understand their nature from the perspective of the project managers who are required to manage international development projects. The government can often influence some of these factors.

Political Factor

Political factors refer to issues at the national level and regional level including inconsistency in policies, laws and regulations, and political instability. From development project's perspective, these factors contribute to an environment of uncertainty on return of capital investment. For example, political uncertainty and lack of transparency in policy decisions affected the growth of cellular network of RPG Cellular project in India. In most of the instances, the probability of occurrence of political factor is small but its impact is relatively large.

Political instability coupled with underdeveloped institutions and lack of awareness in the people may result in frequent change of governments or stimulate abrupt change of policies adversely affecting the successful achievement of development project objectives. Several associated factors that may prompt political challenge to the project are:

- Political takeover or military coup
- War or revolution
- Allegations of corruption causing government resignation, and
- Nationalization of assets with or without adequate compensation.

Legal Factor

Legal factors refer to unexpected changes in government policies pertinent to laws and regulations and currency conversion; absence of appropriate regulatory systems; rates and methods of taxation including customs, royalties, convertibility of currency; role of local courts in arbitration; and the methods by which electricity tariffs are set and approved.

Cho (1999) attributes the legal challenge to the change in any legislation or agreement set by the government related to the following issues: pricing, taxation, royalties, ownership, arbitration, convertibility, corporate law, accounting rules, funds remittances, process regulation, and environment issue.

Cultural Factor

In the context of international development projects, cultural issue is the least known but the most hazardous. Staudt (1991) states that "Understanding culture is the starting point for learning the meaning of development [management], the values that guide people's actions, and the behavior of administrators...Cultural differences emerge in many types of development settings, from assumptions to project design to technology transfer and management styles."

In international development projects, many of the financial institutions require recipient countries to engage foreign consultants to assist with project preparation and implementation due to lack of the needed technical or management skills available in the recipient countries. The international consultants have different socio-cultural background than the beneficiaries, may not be familiar with local resources, and are accustomed to different approaches to engineering and project management practices. This causes conflict of interests, extra pressure on executives, and frustration, which restrains or obstructs project progress and often leads to lost opportunities, directing of development efforts at wrong groups, project cost overrun, and schedule delays.

Cultural misfit of the project objectives and a lack of local knowledge and understanding can result into rejection of the project by the intended beneficiaries. In order for these projects to be successful, the project manager must take cultural factors of traditions, values, customs, and beliefs into consideration at the project planning stage itself so that project objectives are consistent with the values and customs of the beneficiaries.

Technical Factor

Technical factors refer to use of technology including design, engineering, procurement, construction, equipment installation, and operation of the equipment and its compatibility with accomplishment of project objectives. International development projects are located in the developing countries, which lack adequate resources, technical and managerial skills, and have low human capital productivity. Therefore, project design standards, specifications, and construction methods must be carefully selected so that they will be appropriate to the local financial, human, and material resources required during both the implementation phase of the project and its subsequent operation.

Managerial/Organizational Factor

Managerial or organizational factors refer to inadequate or ineffective management of the project by project sponsor or project management agency. The events in managerial factors include the following:

- Inadequate communication
- Unclear objectives
- Too optimistic goals in relation to project cost and schedule
- Lack of project sponsorship
- Unclear lines of responsibility, authority, and accountability
- Slow and cumbersome decision-making process
- Lack of training of the local staff for sustainability, and
- Lack of end-user participation.

For example, the lure of soft funding from the World Bank pushed the approval of Haryana State Power Restructuring Project in Haryana, India without a clear understanding of the project objectives and strategy to accomplish the goals (Devasahayam, 2000).

Economical Factor

Economic factors refer to the issues influencing the economic feasibility of the project including the changes in domestic economic conditions of the recipient country or inaccurate project development plan due to unpredictable economic conditions. This may be caused by increased competition, decreased consumption, and regulatory changes requiring changes in selling price of the product or renegotiating concessions awarded to the project and would reduce the profit margin. In Pakistan's AES Pak Gen Project, regional power authorities sought tariff reduction after change of government. This conflict has still not been resolved, as the company states that tariff reduction will erode their profits (The News, 2000).

ENVIRONMENTAL FACTOR

Environmental factors refer to issues in conflict with established environmental regulations of the recipient country. This comprises pollution related issues such as noise, air pollution, water pollution, and visual disturbances and those related to natural resources such as unsustainable use of natural resources including minerals, water, land, and flora and fauna. For example, in Upper Bhote Koshi Hydroelectric Project in Nepal, vibrations due to construction caused house cracks, dusts, noise, and mud (Ghimire, 1998).

Until mid-1980s, environmental concerns fared far less in the development of project appraisal, as the basic benefit-cost criterion was the main consideration for selecting projects. Lately, the IDFIs have realized that severe environmental degradation can affect a country's macro-economic performance over the long run. If not dealt with appropriately and early, environmental problems can eventually impose a heavy burden on an economy and hamper country's economic growth. To counter such denigrating effects caused by development projects, Wilson (1997) suggests integrating a proper valuation of the environmental effects of the projects in order to improve the conventional methods of project evaluation.

Social Factor

Social factors refer to social environment of the recipient country and encompass the following:

- Hostility due to religion, customs, and ethnicity of the project participants
- Social uprising or riots due to ethnicity or polarization of social strata (i.e. rich may become richer and poor become poorer thus increasing rich to poor gap)
- Security of the stakeholders
- Overestimation of capacity of the beneficiaries, and
- Resistance of the beneficiaries to new social values and standards or to absorb the effects of economic change or new technology.

For example, in Haryana State Power Restructuring Project in Haryana, India, fixing of tariff on cost-plus basis, and its continuous revision every year and strong opposition from vested interests due to loss of jobs is generating opposition to economic change (Devasahayam, 2000).

Corruption Factor

The World Bank defines corruption as "the abuse of public office for private gain". Inevitable politics interference coupled with lack of transparency and lack of regulatory institutions, bribery and corruption are widespread in international development projects resulting in ineffective use of development resources. Corruption is based on using unlawful influence to extract additional costs to receive or give a preferential consideration in connection with awarding and agreement to a project developer. The project developer includes these costs into the project development cost. The higher these costs are, the lower the returns from the project investment will be.

In Thailand, Mahitthirook (2000) estimates that 10% of the project cost is lost to corruption due to the following six factors which enable corruption to take place.

- State agencies and politicians that implement projects.
- Lenders that may favor some contractors.
- The delegation of architects, engineers, supervisors, and consultants responsible for each project.
- Panels inspecting and accepting finished projects.
- Contractors who are ready to buy projects with bribes.
- Laws and regulations that can be misinterpreted to favor any parties.

Rajghatta (1997) states that during the 1980s in India, only about 14 percent of the money marked for development actually reached the end user. In order to retain the confidence of their shareholders and the public, the IDFIs have acted and are combating corruption in development projects by control of fraud and corruption and institutional strengthening.

Physical Factor

Physical factors refer to the circumstances beyond the project developer's or government's control such as natural disaster (e.g. fires, floods, drought, lightning, typhoon, earthquake), wars, hostilities, military coups, civil strife, and acts of terrorism. Developing countries provide unmeasurable instances of such events. A competent international development project manager should have a good understanding and judgment of the conditions in the recipient country and mitigate these.

SUMMARY AND RECOMMENDATION

The history of international development projects is fraught with plenty of challenged projects. In this paper, various factors causing the projects to be challenged are classified based on their nature and discussed. Because of inherent complexity and various problems associated with international development projects, development agencies in a report on identifying personality attributes for international development managers concluded that "the personal qualities contributing to success in jobs in industrialized countries may not be the most useful in developing countries" (Lethem and Cooper, 1986). Thus, the project manager must appreciate the environment of development projects, maintain flexibility, and be competent to analyze the nature of associated problems and their adverse effects on the success of the project, and address these promptly. Table 1 summarizes these 10 factors and their impact.

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	Factors	Characteristics	Impact
1	Political	Inconsistency in policies and regulations; political instability, war, revolution; import restrictions. Low probability, high impact.	Environment of uncertainty on return on investment
2	Legal	Unexpected changes in laws and regulations policies; currency conversion; lack of appropriate regulatory systems; role of local courts in arbitration.	Lack of conducive environment to foreign investments; Restricted technology transfer.
3	Cultural	Differing social-cultural background of stakeholders; different thought process.	Conflict of interest and extra pressure on executives; inefficient use of resources
4	Technical	Use of technology incompatible with project; use of incompatible standards for manufacturing and services.	Under performing or unsustainable project; stakeholder dissatisfaction.
5	Managerial /	Inadequate or ineffective project management; lack of	Project failure; stakeholder

	Organizational	appropriate processes or resources.	dissatisfaction.
6	Economical	Changes in domestic economic conditions; increased competition; regulatory changes.	Project unsustainable or cancelled.
7	Environmental	Pollution-noise, air, water, visual; unsustainable use of natural resources.	Environmental degradation; social resistance to economic changes
8	Social	Ethnic hostility; religious fragmentation; security of stakeholders; resistance of beneficiaries to new social values.	Lack of foreign investment or technology flow.
9	Corruption	Political participation in investment decision making; lack of regulatory institutions.	Ineffective use of development resources.
10	Physical	Circumstances beyond anyone's control- natural disasters; wars, coups, acts of terrorism.	Lack of foreign investment or technology flow.

Table 1 Critical Success Factors for International Development Projects

Managing Foreign Exchange Risk on International Construction Projects

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ABSTRACT

Managing the foreign exchange risk is critical to achieving financial success on many international construction projects. Every transaction that crosses national borders results in exposure to foreign exchange risk. Without proper management, a small movement in the currency exchange rate can turn an international project from a profit to a loss. This paper addresses the primary foreign exchange risks, translation and transaction risks, and suggests strategies for managing these risks. A case study is presented illustrating the application of foreign exchange exposure management during the life of an international construction project.

INTRODUCTION

One of the major challenges on international construction projects is managing the foreign exchange risk. Every transaction that crosses national borders results in exposure to foreign exchange risk. Foreign exchange rates can be volatile. The changes are difficult to forecast. The direction, magnitude, and timing of changes are outside the control of any construction firm. Without proper management, a small movement in the exchange rate can turn an international contract that has a large volume of currency exchange from a profit to a loss. This is a major problem in third world countries where there is a growing demand for construction of modern infrastructure.

This paper addresses the foreign exchange risk associated with international construction projects. The risks can be grouped into two categories: translation and transaction risk. Various strategies and financial instruments that are available to manage these foreign exchange exposures are examined. A case study illustrating the application of foreign exchange exposure management to the major stages of a hypothetical project is presented. Major findings indicate that a contractor must incorporate expected future exchange rates in bid preparation and then hedge cash flows during project execution.

FOREIGN EXCHANGE MARKET

The foreign exchange market is the place where currencies can be bought or sold. It primarily is an electronic market linking major international banks and financial institutions. Most currency transactions are between major banks, and access to the market is limited to major banks and foreign exchange brokers or dealers. Exchange rates are constantly changing based on the supply and demand for each currency.

Currencies are traded primarily as bank deposits. In the foreign exchange market, one is actually selling a deposit of one currency for a deposit of another currency. The price at which these deposits are exchanged is known as the exchange rate. The exchange rates determined in the interbank market (wholesale level) are rates that banks trade among themselves. The retail exchange rates used by banks with their customers are based on the interbank rates. Retail exchange rates are quoted as a *bid rate* and an *ask rate*. The banks are willing to buy currency at the bid rate and sell currency at the ask rate. The difference between the bid and ask rates is known as the spread, which is the source of profit for the banks engaged in currency exchange. Currency exchange rates tend to be influenced by the rates of inflation, the interest rates, and the economic and political conditions of the countries whose currencies are to be traded.

Many countries impose foreign exchange restrictions or controls to prevent currency speculation and to protect their reserves. These restrictions affect the availability and value of a currency. These controls are designed to limit a customer's ability to freely convert one currency into another. Permission to exchange the currencies must be given by the central bank of that country before the transaction can occur.

FOREIGN EXCHANGE RISKS

When a construction firm has foreign currency exchange exposure, it incurs a risk that the price of the currency will change. The magnitude of the risk is related to the volatility of the currency exchange rates and the amount of currency that needs to be exchanged. The risks faced by an international contractor can be grouped into two categories: translation risk and transaction risk. Each will be discussed in the following sections.

Translation Risk

Translation risk, also known as balance sheet exposure, concerns the impact of exchange rate movements on assets and liabilities denominated in foreign currencies. It arises from the need to convert the financial statements of operations in foreign countries from those countries' local currencies to contractor's national currency (Ball and McCulloch, 1999). The translation risk is due to the need to report international operations in the firm's consolidated financial statement. Normal accounting standards require that all items in a financial statement be denominated in a single currency, which usually is the national currency of the construction firm. For example, suppose a United States construction firm is doing a project in Mexico and is paying for labor and materials and receiving progress payments in Mexican currency. The dollar value of assets and liabilities related to the project will vary as the exchange rate between the dollar and the Mexican peso changes.

Transaction Risk

Transaction risk, also known as cash-flow exposure, occurs when one currency must be exchanged for another, such as receivables denominated in one currency and expenditures denominated in another (Shapiro, 1999). The transaction risk involves uncertainty regarding cash flow. Transaction risk is measured currency by currency and equals the difference between the value of contractually-fixed receivables and the value of project expenditures for labor, materials, or subcontractors.

EXPOSURE MANAGEMENT

There are a variety of exposure management techniques that a construction firm can use to minimize or avoid foreign exchange risks. Some of these methods are designed to alter the exposed positions of the firm, and others can be used to offset the risk of exchange rate fluctuation. Currency management techniques that will be discussed are divided into two categories: internal and external. Internal techniques refer to those that are available within a company, and external techniques involve the use of external institutional services and financial markets.

Internal Management Techniques

If construction materials are imported and the currency in which they are invoiced is expected to appreciate against the currency in which the contractor receives payment from the client, the contractor could pay the invoice immediately to reduce the transaction risk. The contractor may require more working capital to adopt this technique and would need to compare the cost of the additional capital with the expected amount of appreciation.

Another technique is to denominate expenditures in the same currency as income. This reduces the transaction risk, but depends on suppliers, subcontractors, and labor accepting payment in the same currency as the contractor is being paid. As an alternative, the contractor may be able to negotiate contract terms that provide for payment for imported materials in the same currency as they are invoiced.

Some contractors chose to minimize their currency exchange risk by submitting tenders only on contracts that are denominated in strong currencies such as the United States dollar or the Japanese yen. On such projects, the contractors may be able to negotiate with their suppliers, subcontractors, and suppliers so that all payments can be made in the same currency as the contractor will receive payment.

Asset and liability management techniques can be used to manage the translation risk. The approach is to increase exposed assets denominated in strong currencies and to increase exposed liabilities in weak currencies (Kettle, 1985). When a currency is expected to appreciate, the construction firm should attempt to build up cash, short-term investments, receivables, and inventories denominated in that currency. Conversely, if currency devaluation is expected, the firm should increase its liabilities, payables, and borrowing.

External Management Techniques

A construction firm working for a client in a country whose currency is weak and has to invoice in the currency of that country can hedge against the risk of devaluation by offsetting the receivables by securing a loan in the local currency. The firm can then use the client's periodic payments to repay the loan. This creates a matching of currency inflow and outflow and transfers the devaluation risk to the lending institution.

If a construction company has foreign currency outflow commitments, such as for imported materials, it can hedge its currency exchange rate exposure by making investments in the foreign currency. The contractor can them make the invoice payments by liquidating the investment and avoid the exchange rate risk.

Contractors can purchase forward exchange contracts to hedge against exchange rate fluctuation. Contracts can be negotiated with banks for almost any maturity from a few days to several years in the future. Most banks regularly quote forward exchange rates on 30-day, 60-day, 90-day, 180-day and 360-day contracts for a relatively small number of currencies, such as the United States dollar, the Japanese yen, and the British pound. However, construction firms may negotiate forward contracts in other currencies with international banks. The use of forward exchange contracts is a common strategy for hedging the exchange rate risk.

Another technique is to purchase foreign exchange contracts from a futures exchange, such as the International Monetary Market of the Chicago Mercantile Exchange. These exchanges allow a construction firm to purchase a foreign exchange contract for future delivery of a specific quantity of foreign currency at an exchange rate that is fixed at the time the contract is purchased. The futures contracts can be bought and sold at any time before maturity, but they are less flexible than the forward exchange contracts. Only a small number of currencies are traded in the futures exchanges, available contract sizes are standardized, and limited maturity dates are available.

The last external technique that a contractor may use is to purchase a currency option from an options exchange, such as the Philadelphia Stock Exchange. A currency option gives the buyer the right, but not an obligation, to exchange a certain amount of currency at an agreed price. The seller of the option must fulfill the option contract if the buyer chooses to exercise it, but the buyer is not obligated to exercise the option.

FOREIGN EXCHANGE RISK MANAGEMENT

In order for a construction firm to manage its foreign exchange exposure, it must first decide how much risk it is willing to assume. In general, there are two alternative strategies that the company could adopt. Either it could accept significant risks to maximize the potential benefits of exchange rates, or it can seek to minimize potential losses, which may mean reduced profits. After the risk management strategy has been selected, the next step is to identify the size and nature of the firm's foreign exchange rate exposure. Risk management strategies then must be selected for that part of the exposure risk that the contractor is unwilling to assume.

Some construction firms favor the approach of managing the currency exchange rate risk from the home office, while others favor a decentralized approach. The advantage of allowing foreign offices manage their exchange rate exposure is that local managers frequently are in the best position to judge the timing of cash flows, exchange rate changes, and local government and economic situations. However, centralized currency exchange exposure management is recommended by many experts. As the size of currency exchange transactions becomes larger, the company gets more competitive exchange rate quotations from banks. A centralized system allows the company to implement internal hedging techniques, such as matching the currency denomination of receivables and payables across the company. Effective currency exchange risk management requires professional expertise, and a centralized approach minimizes the size of the staff required to manage the currency exchange exposure.

The next section contains a hypothetical case study that illustrates the use of some of the currency exchange exposure management techniques.

CASE STUDY

Acme Construction Company (a United States firm) has received an invitation to submit a tender for the construction of a power plant in Malaysia. The client requires that the proposal be submitted in Malaysian ringgit. The major electrical and mechanical components will be purchased from vendors in the United States and Japan. Many of the other construction materials and much of the skilled labor will need to be imported. The President of the company is interested in submitting a tender for the project, but is concerned about the currency exchange risk.

The company will be interested in the dollar value of its cash flows, because its financial statements are prepared in that currency. Consequently, the preparation of the proposal will be made in dollars and then converted to ringgit. There will be significant transaction exposure, because income will be denominated in Malaysian currency, and project expenses will be denominated in dollars, Japanese yen, Thai baht (for skilled labor), and ringgit. Because the currency exchange rates may change during the period of the contract, the dollar value of cash flow is uncertain. To prevent the fluctuation of exchange rates from reducing the dollar value of the cash flow, the firm should hedge its exposed currency position. This means establishing an offsetting currency position, such as a forward or option contract.

The first step in minimizing foreign exchange exposure is to prepare a realistic cost proposal that incorporates anticipated future exchange rates. Because foreign exchange rates change constantly, it is unwise to estimate the project cost in dollars and then convert the value to ringgit. Instead, the following steps should be used to consider the effects of anticipated exchange rate fluctuation.

- Determine anticipated cash flows by currency and anticipated time of occurrence.
- Translate the cash flows denominated in foreign currency into dollars using forecast exchange rates for each currency and time period.
- Determine the total project cost in dollars.
- Determine the total project cost in ringgit using the forecast exchange rate for the anticipated contract award date.

To protect itself during the period between submission of the tender and receipt of the contract award, the construction company should take option positions in the foreign currencies. There is no obligation to exercise these options, so the maximum cost to the company would be the cost of purchasing the options. Options to purchase Japanese yen and Thai baht and an option to sell Malaysian ringgit should be purchased.

Once the contract is awarded, Acme should review its cash flow forecast to determine the timing and amount of currency to be exchanged and the anticipated net profit. Forward contracts should be purchased to protect against both the transaction and translation risk.

CONCLUSIONS

Management of the currency exchange risk is critical if a construction company is to be successful in the international market. Unanticipated exchange rate fluctuation can turn a profitable project into an unprofitable one. Contractors face two exchange rate risks. Translation risk results for the need to convert the financial statement of the foreign operation from the local foreign currency into the contractor's national currency. Transaction risk occurs when one currency must be exchanged for another. Various internal and external exchange rate exposure management techniques were discussed. Anticipated exchange rate fluctuations should be considered in developing bids or proposals, and cash flows should be hedged during project execution.

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Real Options, a Decision Making Tool for Construction Projects

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ABSTRACT

Managerial flexibility has always been important in construction projects; however, in today's global market, managerial flexibility is even more vital for responding to changes. Traditional tools fail to measure it, but the Real Options Approach (ROA), which brings the strategies of the financial market into real projects, can assist us in making better decisions. Sequential compound options are a common problem in construction projects. Through a case study, it is shown how managerial flexibility can add value to a project and how it can be measured.

NEW TOOL FOR DECISION MAKING

For a long time, decision-making has been tied to strategies fixed in advance. Decisions are made before the projects start. Scheduling and budgeting are shielded from the truth, and many times they create an illusion of certainty. When a project is running on schedule, it is usually attributed to good management.

However, we need to move to a more active management. In advance, the project manager should look at all alternatives and options involved in the project, and in advance, he or she should know what action to take when information arrives. Additionally, active management allows project managers to take action, thus making options more valuable.

Managers often want to have a crystal ball that will help them when a decision has to be made. Traditional tools like Net Present Value (NPV), Discount Cash Flow (DCF), and Decision Tree Analysis (DTA) fail to capture the managerial flexibility and many times kill the projects before managers can prove that managerial flexibility can add value to a project. When managers decide to start a project with negative NPV, it is because experience or some sort of rule of thumb tells them that they can profit at the end, even though they have no evidence for their intuition. In this paper, a new tool is presented. This is the Real Options Approach (ROA), which allows us to have more insight into a project than do traditional tools. The Real Options Approach brings the strategies of the financial market into real projects and helps management make better decisions.

Real Options Approach

The Real Options Approach is based on the Black–Scholes model for call options. Black and Scholes developed the formula in 1970 and, since that time, their formula has been used in the financial world. Only after Merton and Scholes received the Nobel Prize in Economics in December 1997 did a group of researchers start to apply it to real projects, most of them related to oil or mineral exploitation and R&D for pharmaceutical firms. Only a few research studies can be found showing ROA applied to construction areas or development (Garcia-Saenz 2001). With ROA, decisions like delaying or accelerating a project, expanding or contracting, waiting to build, or abandoning a project, can be quantified, and the consequences of these decisions can be tracked.

Projects and Labyrinths

Projects and managers are similar to labyrinths and competitors. Suppose that two competitors need to go from point A to point B as shown in Figure 1. Also, both of them have the opportunity to study the labyrinth before attempting it.

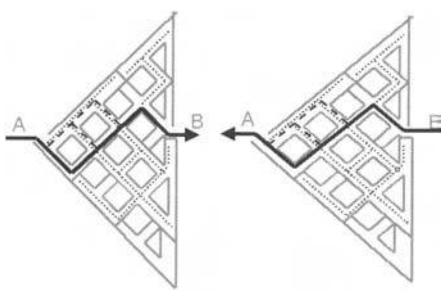

Figure 1 First competitor's solution to the maze

The first competitor, being a cautious person, decided to go and analyze the consequences of each action every time he needed to decide between two ways so that he would choose the shortest route. After reaching point B, he returned to point A by moving backwards and measuring the consequences of each decision in each node. For the calculations, a rate free of return was used instead of a market rate. Option valuation always uses a risk-free rate instead of a market rate because the consequences of a decision are known before the time has arrived and before decisions are made. Therefore, there is not risk involved. He was ready for the competition. The second competitor considered the problem typical and decided that he knew the game, his previous training was more than adequate, and in the end, there was no single solution, so he felt confident he could find a way to point B.

Projects are labyrinths of decisions, and managers are the competitors that want to solve them. Active managers, like the first competitor, start the project by analyzing all the decisions that need to be made and their consequences. Passive managers, like the second competitor, know that calculations are always made with some margin that covers for bad decisions. Passive managers think that there will always be money left if they finish the project both on time and within budget. They are convinced of this because traditional tools always use the market rate to discount any expense regularly with a big margin for security.

It is easy to recognize that the first competitor, the active manager, is going to do a better job during the competition. If each decision implies a gain in time and money, the first competitor, who previously calculated all the consequences, is going to outperform the second one since the latter one will have to lose money and time in each decision, which will not lead to point B.

SIMPLE CALL OPTION

An option is an opportunity to make a decision. Construction projects are full of options, and economic results depend on the actions taken when decisions have to be made. Some-times, decisions are expensive for projects but they can return greater benefits if made even when traditional tools cannot measure them.

Call Option (*C*) is the right to buy something and pay a price for it (*E*) within or before a specific date [1] *(T)*. If the option is exercised before maturity, it is called an *American option*; if it is exercised at maturity, a *European option*. The buyer has the right to buy (or not to buy) a specific asset for a specified amount of money any time before a specific date, called the expiration date. At the expiration date, the buyer exercises the option only if it is a smart thing to do; otherwise, the option can be thrown away. He or she will make the decision to buy the asset if it is worth more than the exercise price at the moment of the decision. In option nomenclature, we can write:

[1] This date is the expiration date of the option, after this date, the option is dead.

$$C = \begin{cases} 0 & \text{if } S_T \leq E \\ S_T\text{-}E & \text{if } S_T > E \end{cases} \tag{1}$$

The value of the option *(C)* is zero if the value of the asset is equal or less than the exercise price[2] (*E*) and the owner of the option does not exercise his right. If the value of the asset[3] (S_T) is greater than the exercise price (*E*), the owner will exercise the option, and its value is the difference between the value of the assets and the exercise price *(S_T-E)*. In real options the call option *(C)* is the difference between the market value of the project minus the expected cost if the options are exercised at maturity.

OPTIONS VALUATION

The valuation of an option can be obtained using either risk neutral probabilities or the method of replicating portfolios. Both methods are mathematically equivalent. The risk neutral probability approach is a consequence of the law of one price: "Two assets that have the same future pay off must have the same current value."(Amram & Kulatilaka 1999). Merton's contribution to this methodology is related to the arbitrage piece. He added that Black and Scholes' formula can be used when arbitrage does not exist. "If the prices were not identical, arbitrage will exist. 'Black and Scholes' formula has to be free of arbitrage" (Merton 1973). The second method is based on Black and Scholes' (1973) explanation that a strategy of borrowing to finance a purchase duplicates the risk of a call. It says that nobody wants to pay a higher price for something that can be replicated with money borrowed risk-free. By knowing the actual value of a project, we can determine the price of a call. Both methods work in a similar way to the analogy at the beginning of this document. Once the problem is established, to calculate the value of the option, calculations are done backwards using a risk-free rate of return instead of a risk rate.

Real options can be a simple real option or an individual real option. Individual options can be classified into growth options like expand, switch, or contract; learning options; and abandonment options. Real-life projects often involve a

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[2] The exercise price is the fixed price at which the holder can buy or sell the underlying asset; this value should not be confused with the value of the asset at a given point in time.

[3] The underlying asset is an asset with the same risks as the asset that the firm would own if the investment were made. In stock options, *S* is the price of one share and in real options; it is the market value of an identical asset (for example an identical building).

collection of various options. The basic types of real options can also occur in combinations such as compound options. Compound options can have the same life and occur at the same time. This type of compound options is called simultaneous compound options. Compound options can be sequential options; the life of the second options occurs only when the previous option is exercised. Most engineering and construction projects have several phases and can be viewed as sequential options, where later options are available only if an earlier option is exercised.

Myers (1977) has suggested that corporate investment opportunities may be represented as options, and Genske (1977) has derived formulas to value subordinated debts as compound options. According to Genske, changes in time in the value of a call can be expressed as a function of changes in the value of the firm. Engineering and construction projects require a design phase before starting the construction phase. Phases make this type of project a perfect candidate for the analysis of sequential compound options. The flexibility to decide the construction phase after the design phase is ready adds value to the project, even though flexibility cannot be measured with traditional tools. Fortunately, nowadays, ROA can do that. The option value is the part that we need to add after the NPV is calculated and is the additional part that traditional tools cannot measure. To evaluate a construction project with traditional tools requires the decision to build at a specific time in order to have a cash flow and use it to calculate the NPV. The decision to build has to be done in advance. With real options theory, decisions can be made after waiting to see how events unfold. If events are favorable, the option is exercised: if events are unfavorable there is no obligation to exercise it.

CASE STUDY (SEQUENTIAL COMPOUND OPTION)

Let us consider an example of a construction company that wants to build a project where the design phase would cost \$35,000 and the construction phase, \$330,000. Let us assume that the value of the project could go up 15% (u=1.15) or down 13%[4] (d=1/u). Ups and downs are related to volatility prices (Hull 1997).

We are going to assume that the risk-free rate is 5% (r_f). The twin asset would be a building identical to the one we are planning. If it existed, it would have a cost in today's dollars of \$350,000. To simplify the problem, we are going to assume that this project is the only equity of the firm, so the value of the firm is the same as the value of the project.

The problem needs to be worked on backwards, just like the maze that is solved from the destination to the source. Consequently, we first need to value the equity

[4] Actually it could go down by (1-1/1.15)%=13.0435%.

of the construction phase as an American call option whose exercise price would be equal to the debt ($330,000). Let us assume that the debt will be due in three years. After this, we can analyze the design phase as a compound option of $35,000 maturing after a year. Figure 2 shows the event tree for the project with all the possible payoffs at years 1, 2, and 3. It starts with the actual value of the project, that is, the value of the twin asset and considers each year the possibility of going up by 15% and down by 13%.

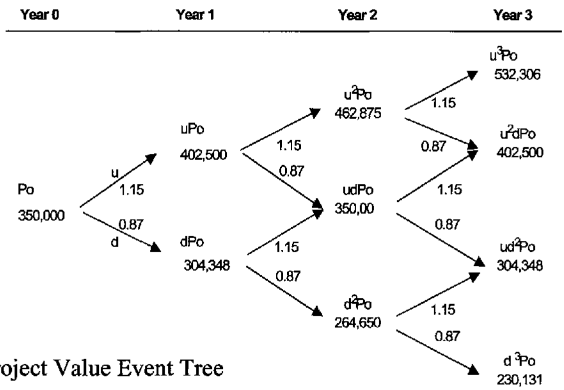

Figure 2 Project Value Event Tree

The first method we are going to use to value the option is the risk-neutral analysis. The project has a current value of $350,000. After considering all combinations, we can see that in three years, its value could range from $230,131 ($d^3Po$) to $532,306 ($u^3Po$).

Now, what would be meaningful for us is to find the probability of having a project today with those payoffs. We can calculate this probability because there is a relation between the current price of the project and the expected payoffs at the end-of-period. Figure 3 illustrates this for a one-year period. The present value of $350,000 is equal to the expected cash flow at period one, discounted by the risk-free rate, which means that we can express *Po*, as shown in Equation 2, as a function of *Pu* and *Pd* according to their risk-neutral probabilities (*u*s and ds are for the ups and downs).

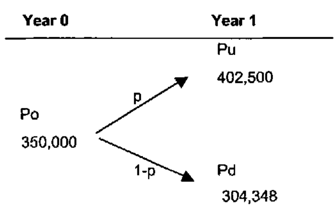

Figure 3 Risk Neutral Probabilities

$$Po = p \cdot \frac{Pu}{(1+r_f)^t} + (1-p) \cdot \frac{Pd}{(1+r_f)^t} \tag{2}$$

Solving for p [5] from the above equation and using t=1, we have:

$$p = \frac{(1+r_f)^1 \cdot Po - Pd}{Pu - Pd} = \frac{(1+r_f) \cdot Po - u \cdot Po}{u \cdot Po - d \cdot Po} = \frac{(1+r_f) - u}{u - d} = .64 \tag{4}$$

Under the risk-adjusted discount, the probabilities p and (1-p) are called the objective probabilities for the up state and down state volatilities respectively. If we use these probabilities as well as the risk-free rate, we will obtain the same tree node values as those shown in Figure 2.

We can now consider the construction phase first. A debt of $330,000 is derived from the option to build three years from now. Figure 4 illustrates the option valuation as well as the decisions that would be appropriate (decision to wait, not to wait, to exercise the option, or not to exercise it).

The first step is to determine the call option value by using Equation 1. The exercise price is the $330,000, and the value of the project is the one that we would have at year 3, which, as we discussed previously, can be one of four different values (see Figure 2) The call option value would then be the maximum between zero (i.e. we do not exercise the option) and the difference between the tree node and the exercise price.

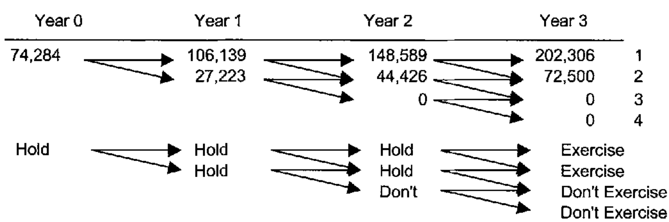

Figure 4 Option valuation of debt of $ 330,000

[5] The result of the probability that we report has been rounded off so be careful when verifying our results.

Let us then consider the first row of the table above. The call option value would be equal to max {(532,306 - 330,000), 0} = \$202,306. It is important to be reminded that we are now dealing not with prices but with the equity of the company (since we assume the company was only doing this project). Given that we obtained a positive value, the decision associated with this case will then be to "Exercise" the option. As we can see, only the cases where we ended up with zero correspond to the states where the option should not have been exercised i.e. "Do not exercise." Now the tree needs to be worked backwards using the probabilities we found above and the risk-free rate.

Continuing backwards, the first stage (row) of the second year would have an expected value derived from the first and second stages of the third year. (Try to imagine that the arrows used in the figure have been reversed). So the call option value for this case will be

$$\frac{p \cdot 202{,}306 + (1-p) \cdot 72{,}500}{(1+r_f)^1} = \$148{,}589 \tag{5}$$

Similar calculations are performed to get the value of the option at years 1 and 0. A positive option value at year 0 indicates that the asset/project with an actual value of \$350,000 can support a debt of \$330,000.

Because we are making calculations backwards, we need to consider if the design phase debt can be supported at year 1. The reason why we have been talking about debt is because compound options can be seen as subordinated debts, and changes in time in the value of a call can be expressed as a function of changes in the value of the company (Genske 1979). We need to ask if the company having an asset/project with an actual value of \$350,000 and an original debt of \$330,000 due at the third year can support another debt of \$35,000 due in the first year. Figure 5 contains the new option valuation and the decisions for each scenario.

The years 2 and 3 are exactly the same as those in Figure 4 because only one debt is alive and it is due at the end of the third year. Now, year 1 changes because we have to introduce the debt of \$35,000. So we will in this case take the maximum between zero and the difference between the results from Figure 4 and the exercise price of this option, \$35,000. For the first stage (row) of year 1, we will then have the call option equal to max {(106,139- 35,000), 0} = \$71,139.

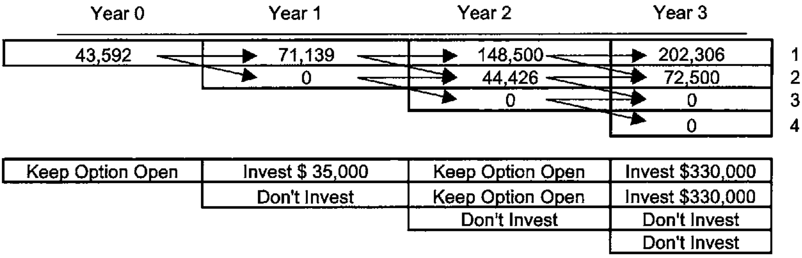

Figure 5 Sequential Compound Options

At this point, we need to examine which scenario would be more advantageous to us: either going backwards to year 0 using the risk-free rate and the probability p found above and assuming that we invested the 35,000 in year 1, or investing the $35,000. The value of the latter alternative will simply be the difference between the call option at year 0 and the exercise price. From studying both alternatives, we discover that it is more advantageous to invest in year 1 than in year 0.

$$\max\left((74{,}284-35{,}000), \frac{p\cdot 71{,}139+.(1-p)\cdot 0}{(1+.05)^{1}}\right)=\$43{,}592 \tag{6}$$

The amount of $43,592 is the money earned because of the flexibility to decide on the construction after seeing how events unfold. The fact that the option value is positive indicates that the company can support another debt at year 1. At the end of the first year, we can decide to abandon the project or make the second investment. I we decide to invest, the second option starts. It has an exercise price of $330,000 and expires at the end of year 3. Observe how the valuation was the result of working the problem backwards; we consider the first option only after we have done our valuation for the second one.

In this document, we mentioned that an option can be valuated with a replicating portfolio. We are now going to valuate the options in order to have a better comprehension of that method. A replicating portfolio is composed of m units of an identical project and an amount B that can be borrowed at a risk-free rate (the sign of this amount is not problematic). We explain this method with the aid of Figure 6. Vo is what we called Po in Figure 2. We still use the u and d to traverse the tree. We proceed backwards from using the option valuation for year 3. Now, we need to add up the money that is borrowed at a risk-free rate and the units of its value to get the call value. That is, to get the value of the first row for year 2, $C_{t=2,1,}$ we need to find m and B, and we do this from what we know about year 3 as illustrated in the same figure with equations (3.1) and (3.2). From these two equations, we solve the only two unknown values: m and B.

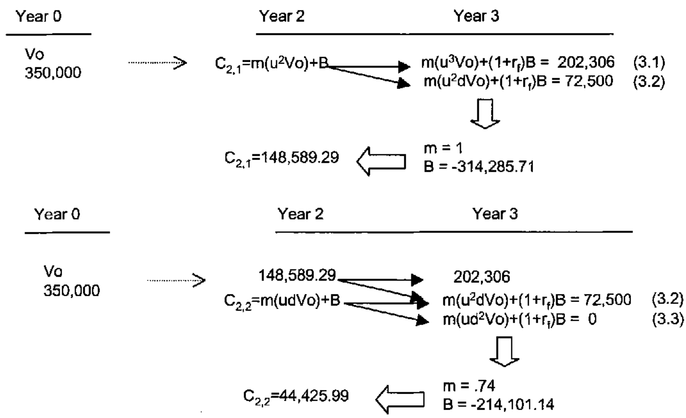

Figure 6 Portfolio Replication, moving form year 3 to year 2

In this fashion, we proceed to determine the option value for the second row of year 2 as illustrated in Figure 6 (based now on equations (3.2) and (3.3)). As we determine the number of units needed for every case and the amount that needs to be borrowed, we obtained the same values as shown in Figure 4. The decisions are exactly the same as in the previous method because the options values are the same.

Also we will need to consider the exercise of the two options along the way. After we know that the company can support a debt of \$330,000 (based on the fact that the option valuation provided some positive outcomes), we can incorporate the option to pay the debt of \$35,000 at the end of year 1, as we did previously.

The years 2 and 3 are exactly the same as those in Figure 5 because only one debt is alive and it is due at the end of the third year. Now, year 1 changes because we have to introduce the debt of \$35,000. So we will in this case take the maximum between zero and the difference between the results from Figure 4 and the exercise price of this option, \$35,000. For the first stage (row) of year 1, we will then have the call option equal to max {(106,139- 35,000), 0} = \$71,139. Similarly, for the row below, the option value is: max {(27,223-35,000), 0}=0. Year 0 can be calculated with the methodology of the tracking portfolio as shown in Figure 7.

m	B	Co
mCu+(1+rf)B = C1,1	B=(Cu-mCu)/(1+rf)	
mCd+(1+rf)B = C1,2		C=mVo+B
0.90	-23,371.66	43,591.91

Figure 7 Tracking portfolio for year 0

The solution is exactly the same as the solution with the Risk-Neutral Probability method.

CONCLUSIONS

The Risk Neutral Analysis is simpler to work, especially when the spreadsheet is used as a tool. Compound options are more difficult to set and solve than single options, but after we know how to work backwards and know that the second options have to be solved first and the first option has to be incorporated into the solution of the second option, future problems become more simple.

Real options are a powerful tool for decision makers. Traditional tools miss many insights that can only be captured through the Real Options Approach. As we move to a more active management, we constantly find new opportunities. Project interactions are no longer captured in the old framework of "accept or reject" only because of the NPV. We need to work in the new business environment where opportunities run out and old plans have to be revised or abandoned.

Opportunities add value. Projects cannot be treated in a static way; they should be integrated with strategic planning and control. Uncertainties create values and flexibility adds value to projects. Project directions must be modified when conditions change with new strategies. Previous knowledge of the consequences of each action allows us to be the precocious competitor at the labyrinth. Projects (especially large projects) take considerable time to complete and can be temporarily stopped or permanently abandoned. These types of projects can have many stages. Each amount of money spent gives an option that may or may not be exercised to go ahead and spend the next amount of money.

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Stimulating competitiveness through technology transfer: a focus on micro enterprise activity in construction

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ABSTRACT

The role of globalisation and innovation in fostering continuous improvement for both the private and public sector has received increased emphasis within the last decade. The activities of micro-enterprises in stimulating and adoption of innovation, both as a practice and its nurturing within any economy plays a key part in this respect. Innovation from any large organisation is often visible due to its scope and impact. Similar developments by their smaller and micro-counterparts, however, have to involve a critical mass of such organisations for its impact to be seen. This is particularly the case in developing economies where organisations classified under small and micro-size, normally form part of the informal sector or hidden economy. The mechanics by which innovation occurs within such smaller and micro organisations and how it translates to the national economy is in many cases therefore, not fully appreciated.

This paper sheds some light on the mechanics of innovation at the micro level by presenting how technology transfer from a developed to a developing economy was employed to bring about innovation among small and micro organisations that operate in construction and its related sectors. It briefly describes innovation and technology transfer as it relates to the context of this paper and how globalisation contributes to both factors. It discusses the mechanisms for the transfer of the technology, and focuses on the aspects of innovation achieved through the impact of the technology transfer. It also identifies some of the difficulties associated with stimulating innovation among the small and micro organisation within the construction sector.

Keywords: Built environment, micro-enterprise, innovation, technology transfer

INTRODUCTION

The activities of micro-enterprises in stimulating and adoption of innovation, both as a practice and its nurturing within any economy plays a key part in this respect. Innovation from any large organisation is often visible due to its scope and impact. Similar developments by their smaller and micro- counterparts, however, have to involve a critical mass of such organisations for its impact to be seen. This is particularly the case in developing economies where organisations classified under small and micro-size, normally form part of the informal sector or hidden economy. The mechanics by which innovation occurs within such smaller and micro organisations and how it translates to the national economy is in many cases therefore, not fully appreciated.

This paper sheds some light on the mechanics of innovation at the micro level by presenting how technology transfer from a developed to a developing economy was employed to bring about innovation among small and micro organisations that operate in construction and its related sectors. It briefly describes innovation and technology transfer as it relates to the context of this paper and how globalisation contributes to both factors. It discusses the mechanisms for the transfer of the technology, and focuses on the aspects of innovation achieved through the impact of the technology transfer. It also identifies some of the difficulties associated with stimulating innovation among the small and micro organisation within the construction sector.

INNOVATION AT MICRO ENTERPRISE LEVEL

The importance of technological innovation and capacity development for micro-enterprises is a theme that is shared by all economies. In developing countries, this assumes a greater significance for achieving economic development objectives (Kumar et al., 1999). The role of micro enterprises is crucial in these economies because they often play a critical part in the embedment of technology and know-how transferred from developed economies. The ability of small enterprises to adopt, adapt and transform existing technological applications and know-how from other environments into relevant and appropriate economic solutions, organisational processes and technological products to match the socio-cultural context of their regional or local industry sector is crucial in bringing about innovation. Innovation in this context is an activity that is often instigated by an external agency, as individual actors involved in such innovation from a developing economy perspective often do not have the capacity to initiate the process. Their essential contribution to the process of innovation however, lies in the transfer of technology and know-how for capacity development.

CONTEXT OF TECHNOLOGY TRANSFER

Technology transfer often presents a complex process that has varied meanings to different audiences (McMaster et al., 1997). In general the context of technology transfer adopted within this paper can be described as the process by which technology, knowledge and/or information developed in one organisation or economic environment, for a particular purpose is applied and utilised in another organisation, or economic environment, for a similar or another reason. The transfer transpires as a gradual process described by Rogers (1995) as a diffusion of innovation. Such diffusion is characterised by a strong personal component whereby any know-how or innovations involved in the process are often transferred through friendships, or close collaborative networks which engender some degree of personal confidence in the host organisation (Robinson, 1988).

THE TRANSFER PROCESS

This section provides an outline on the basic steps of the transfer process as well as the key participants involved in the diffusion of the know-how. Figure 1 presents a schematic approach for achieving a continuous know-how and technology transfer.

The schematic approach comprises eight key stages that are further elucidated in the Table 1 below. The process of transfer depicted in Figure 1 presents the ideal case and in very many projects a deviation from this ideal is somewhat unusual because of the uncertainties intrinsic in technology transfer. In some cases, the transfer process could include only some of the sequences shown in Figure 1.

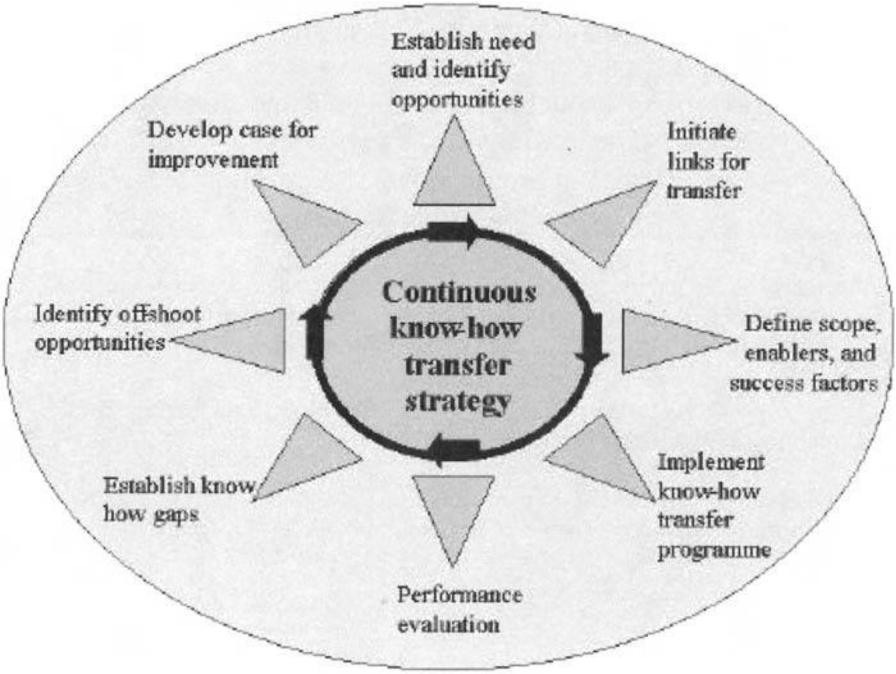

Figure 1. Process for continuous know-how and technology transfer

Table 1 Elucidation of key transfer stages

Stage	Operational activity
I	Establish need and identify opportunities for transfer of technology and know-how.
II	Initiate links for the transfer of know-how. It is essential that the initiation of links take cognisance of the personal element associated with effective technology transfer.
III	Define the scope of the transfer scheme, ascertain close and remote enablers and constraints as well as success factors. This stage forms the transfer appraisal stage.
IV	Devise and implement an appropriate programme for the know-how and technology transfer.
V	Undertake performance evaluation of the transfer scheme based on prior established metrics at appropriate milestones.
VI	Establish know-how gaps between milestones metrics

	and actual performance as well as projected impact of the whole scheme.
VII	Identify off-shoot opportunities and spin-offs that arise as a result of the implemented transfer scheme.
VIII	Develop case for improvement of implemented scheme or any new opportunities for further transfer.

Depending on the degree of formality associated with the transfer the various stages of the process may proceed in a different sequence. Equally, the duration of each stage might last a few days or several years depending on the nature of the transfer project and its scale of implementation. Stage VI of the process is particularly significant, as many know-how and technology transfer programmes are known to progress along paths depicted in Figure 2.

The gap between the realised transfer and unrealised transfer in Figure 2 provides the scope for improvement or new transfer programmes.

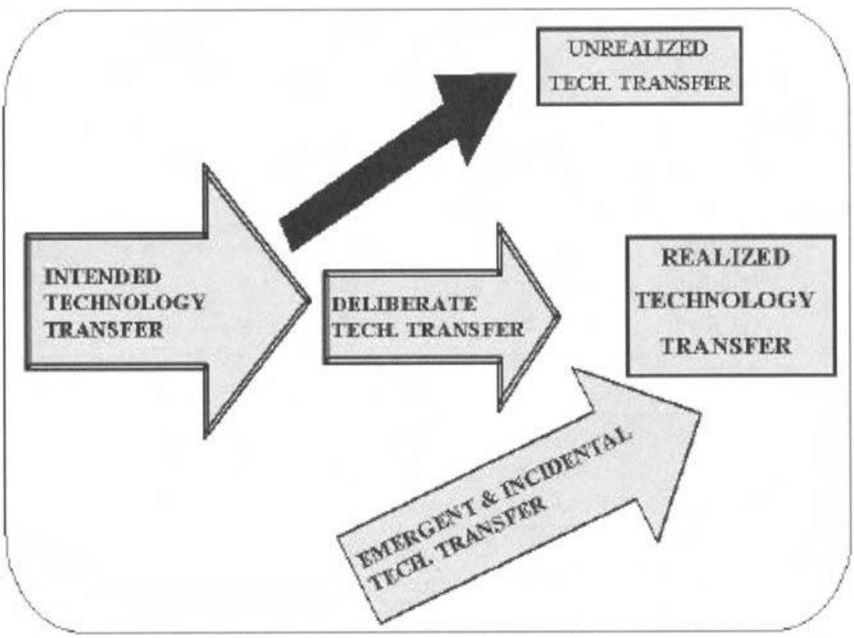

Figure 2 Nature of input-output effect of technology transfer programmes

KNOW-HOW TRANSFER CASE

In many developing economies the conventional financing mechanisms have not been able to serve the people in real need due to the constraint posed by creditworthiness of the poor and lack of appropriate procedures to cater for groups with incomes below national averages. The conventional requirement for collateral such as assets and the evidence to demonstrate that such assets exist practically often excludes the lowest income group. It is therefore common to find small and micro-businesses and local enterprises that are financed entirely from equity, thus limiting the scale of projects and orders their organisations can take up. This situation is not limited to construction and in this case the solution did not emerge directly as a first time transfer of know-how within construction, but rather as a secondary development. What effectively constitutes a spin-off from technology transfer programme implemented in another industry sector.

As a response, to the perennial problem of lack of finance for small enterprises, the Grameen Bank in Bangladesh, emerged as an innovative financing mechanism in the form of *micro-credit* in place. As part of the mechanism put in place was the implementation of know-how transfer on capacity development and financial management. The citing of this case is only for illustrative purposes, and the underlying concept of the micro-credit has found application in several developing as well as advanced economies.

Key participants

The origin of the scheme can be traced back to 1976 to an action research project launched to examine the possibility of designing a credit delivery system to provide banking services targeted at the rural poor. In conformity with the features associated with successful transfer of know-how, the scheme was driven through the personal commitment of Professor Yunus, then Head of the Rural Economics Program at the University of Chittagong, Bangladesh. Successful implementation of the scheme in a village adjacent to Chittagong University saw the extension of the scheme to cover first one disctrict and later to other districts within Bangladesh. In October 1983, the scheme, which had come to be known as the Grameen Bank Project was transformed into an independent bank by government legislation. Currently the Grameen Bank is predominantly owned by the rural borrowers that account essentially for its market. Borrowers of the Bank own ninety per cent of its shares, while the remaining ten per cent is held by the government of Bangladesh.

Micro-credit

Micro-credit is the extension of small loans to entrepreneurs too poor to qualify for traditional bank loans and essentially is was devised as a means for the alleviation of financial barriers faced by micro enterprises. In Bangladesh the scheme provides credit to the poorest of the poor in rural areas without any collateral. The rational of the scheme at Grameen Bank is to provide credit as a cost effective means to mitigate the effects of poverty and serve as a catalyst in the overall development of socio-economic conditions. Currently, the scheme in Bangladesh provides services to approximately two million borrowers including women from the rural areas although initially it was not planned to cover that scale.

The concept underlying the financial arrangement involved in micro-credit has international applicability (Srinivas, 1993). Within Europe and North America this instrument is regularly used, both in government policy formulation, as well as the private commercial sector as part of their lending approach to bridge the income divide for new business starts. The essential features of the scheme in Bangladesh include:

- very small loans given without any collateral (average loan size $100)
- loans repayable in weekly instalments spread over a year
- eligibility for a subsequent loan depends upon repayment of first loan
- individual, self chosen, quick income generating activities which employ the skills that borrowers already posses
- close supervision of credit by the group as well as the bank staff
- stress on credit discipline and collective borrower responsibility or peer pressure resulting in a repayment rate in excess of 98%
- special safegaurds through compulsory and voluntary savings to minimise the risks that the poor confront
- transparency in all bank transactions most of which take place at centre meetings.
- simultaneous undertaking of a social development agenda addressing basic needs of the borrowers
- design and development of organization and management systems capable of delivering programme resources to targeted clientele.

Table 2 presents the performance of the scheme over the last four financial years. This shows a gradual decline in the volume of lending operations (clearly observable in the Housing category). The reduced level of lending is a result of previous borrowers improving their financial capacity and thus, undertaking subsequent task without recourse to the facility provided by the scheme.

Table 2. Performance of the Grameen Scheme

All figures are in USD (Million)

Yearly Loan Disbursed	1998	1999	2000	2001
General (including other infrastructure)	393.90	316.76	268.62	188.49
Housing	20.64	4.58	1.41	0.82
Overall repayment rate (%)	93.52	90.71	88.73	89.57
Number of houses built	491012	511583	533041	543743

Source: http://www.grameen-info.org/mcredit/index.html

SECONDARY TRANSFER TO CONSTRUCTION

While the original scheme was set up to provide finance for agricultural activities, its success has seen an expansion into personal loans to cover other sectors including:

- housing development,
- sanitary projects
- drinking water projects.

This is a clear reflection of the transfer process depicted in Figure 1 and further elucidated in Table 1. More specifically, the identification of other opportunities has assisted in the growth of the transfer scheme to other sectors beyond its originally conceived scope. Equally, there are several rural development projects in infrastructure that are often too small for the well established construction companies to undertake as their size does not provide adequate financial coverage for the higher overheads associated with these bigger organisations. The lack of finance, however had in previous times served as a setback for local entrepreneurs taking up these rural projects. Equally, in many countries beside Bangladesh (including Sri-Lanka, Pakistan and Tanzania), where the public sector is often constrained by resources in the provision of municipal services through traditional contracts, this system of community contract normally provides the solution. The system enables the public sector to engage local people to execute the work, supervise part of the work, and in some cases even fund the infrastructure. The underlying rational of this approach is that users as contractors not only procure the services but also create a sense of belonging for the works and services created. This had a positive effect on the operation, maintenance and sustainability of the infrastructure. In Sri-Lanka this initiative has been scaled up, to serve as one of the mainstream procurement options.

RELEVANCE TO CONSTRUCTION INDUSTRY

Ofori (2002) reiterates the role of the ILO in facilitating construction industry development economies and identifies the improvement of business environment and organisational capacity as a key aspect. While the ILO addresses the organisational capacity through formal training schemes, the case presented in the paper provides the alternative, whereby transfer of know-how for a scheme in another sector diffuses to facilitate organisational capacity development in construction. As part of the spin-offs from the micro-credit scheme in other sectors, the potential for a similar scheme to alleviate the constraints faced by the local micro contractors was identified. Construction projects by nature demand financial outlays that often no one entrepreneur at that micro-enterprise level could sustain. As an innovative feature for the transfer of the scheme to construction, the introduction of partnerships emerged. This ensured that several micro-contractors could pool together their collective credit facilities to undertake projects that hitherto had been beyond their capability. The shared goals and common socio-cultural context contributed to bring about an effective partnership (Bossurt and Geert, 1994). In particular, the role of such organisational know-how transfer and capacity building are presented as essential for achieving development projects that were both economically and socially sustainable (Neale and Miles, 2002).

IMPACT OF THE SCHEME

The immediate impact of the scheme in Bangladesh is best appreciated through the contribution it makes to the national economy. For the period 1994, 1995, 1996 this amounted to a GDP contribution of 1.50% 1.33% 1.10% respectively. In addition the scheme has enabled the following:

- Capacity building at micro-contractor organisational level
- Industry sub-sector development
- Local industry capacity development (ability to undertake works as subcontractors for major contractors)
- Employment generation

- Wider socio-economic benefits

SUMMARY

The transfer of know-how from a developed economy in the form of micro-credit implementation and management to Bangladesh provided an innovative solution for addressing the financial constraints associated with rural micro enterprises. One of the major spin-off of this transfer was the adoption of the scheme to serve the needs of rural construction contractors. The level of finance provided in the case of the Bangladesh scheme has also served as a catalyst for the growth of local partnerships in order to bring about a better financial capacity often required to undertake rural community infrastructure projects. The success of the scheme is attested to by its growth, as well as the degree to which it is reducing external finance requirement for micro-contractors.

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Project duration escalation profile on small and medium construction and engineering schemes

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ABSTRACT

Within construction and engineering, it is not uncommon to find projects that experience schedule overrun. Recent developments in comprehensive scope planning, better constructability initiatives and other productivity improvement schemes have shown that it is possible to minimise or eliminate such schedule overruns. This can be facilitated by the provision of better details to support the accurate estimates of project duration and is usually undertaken for most large-scale construction and engineering projects. The resource input for undertaking such detailed planning on large schemes forms a rather insignificant overhead contribution to the project costs. On small schemes however, this planning and programming effort could form a significant proportion of the overall resource requirement for executing the project. The development of appropriate frameworks to facilitate the estimation of project durations on such small and medium schemes could be of considerable advantage. This could be employed for the accurate establishment of schedules by both project managers and policy makers involved in schemes of a small or medium scale.

The paper provides a background on why current research efforts need to be given to small and medium projects. It then addresses two major issues relating to construction and engineering projects that are classified in the range of small and medium schemes. First, it outlines a conceptual framework for developing and employing project duration escalation profiles. Secondly, it employs field data to establish the levels of escalation for different categories of projects, and explains how the escalation profiles can be employed to assist in estimating project duration for small and medium engineering schemes.

Keywords: Duration, Construction, Small projects, Escalation

INTRODUCTION

Recent developments in comprehensive scope planning, better constructability initiatives and other productivity improvement schemes have shown that it is possible to minimise or eliminate project schedule overruns. This can be facilitated by the provision of better details to support the accurate estimates of project duration and is usually undertaken for most large-scale construction and engineering projects. The resource input for undertaking such detailed planning on large schemes forms a rather insignificant overhead contribution to the project costs. On small schemes however, this planning and programming effort could form a significant proportion of the overall resource requirement for executing the project. The development of appropriate frameworks to facilitate the estimation of project durations on such small and medium schemes could be of considerable advantage.

The paper provides a background on why current research efforts need to be given to small and medium projects. It then addresses two major issues relating to construction and engineering projects that are classified in the range of small and medium schemes. First, it outlines a conceptual framework for developing and employing project duration escalation profiles. Secondly, it employs field data to establish the levels of escalation for different categories of projects, and explains how the escalation profiles can be employed to assist in estimating project duration for small and medium engineering schemes.

RELEVANCE OF SMALL AND MEDIUM PROJECTS

Within the AEC sector, small and medium projects form a greater proportion of the workload undertaken by a majority of the companies. Table 1 for example shows the distribution of new works in Britain and illustrates the dominance of small and medium projects both in the public and private sectors. The data from 1997 is generally mirrored in the construction business environment in that preceding and succeeding annual returns present a similar level on orders for the construction sector in Britain. The high proportion of small and medium projects is not unique to the British construction industry but is reflected across most of the advanced economies including the US (Department of Commerce, 2001). This pattern is not any different in other economies, and is particularly pronounced in developing economies where small and medium projects account for even a much higher proportion of all available works (Langford and Rowland, 1995).

Notwithstanding this dominance of small and medium projects within the AEC sector in most economies, they hardly form the nexus of predictive models that employ project characteristics such as time and cost.

Table 1 Distribution of new projects by size for development schemes

Sub-sector	Proportion of projects by size of order in sub-sector			
	Micro	*Small*	*Medium*	*Large*
Public Housing	36.3	41.9	18.7	3.1
Private Housing	74.2	22.2	3.2	0.4
Infrastructure	69.3	20.8	6.7	3.2
Other Public Works	75.9	17.7	4.5	1.9
Private Industrial	72.0	18.2	7.1	2.7
Private Commercial	76.7	16.0	5.0	2.3

(Source: HCS 1997, The Stationery Office, UK)

MODELLING PROJECT CHARACTERISTICS

Policy makers connected with the delivery of infrastructure and other constructed facilities often have to confront a situation whereby a quick decision is required as to the duration of a particular infrastructure scheme as part of the requirements for establishing a business case to justify the project. In very many cases such a decision must be made before other arrangements, such as financing and detailed planning, can be put in place. The analysis involved in establishing such a business case would usually be quite comprehensive, and relies on the policy maker having a reasonably accurate knowledge of or information on the main features (eg. total schedule) associated with the proposed scheme. A simple tool that provides such information will greatly facilitate the decision of the policy maker at this initial stage of a project.

Several mathematical models for deriving and forecasting some of these features of a project are already in existence. These include models depicted by Seeley (1996), and other works including Flanagan and Tate (1997), Skitmore (1991), and Skitmore and Marsden (1999). The use of these and similar models have been greatly facilitated by the recent developments in IT. Although there have been advances in the deployment of IT systems to facilitate the establishment of the project duration, for example project planning software and estimating these developments, essentially aim at the technical expert who has to go through the full motions of the planning. For the policy maker, whose decision is required much earlier than the detailed design stage of the project, this presents a dilemma. Although the existing models are very useful and convenient for the policy maker, there are two major setbacks associated with them. First, these models have been developed primarily for large projects, and therefore present a scale problem when applied to small and medium projects. Secondly, most of the models simply turn out only cost estimates. These estimates are not associated with potential project durations, which are equally essential for the appraisal process of the development schemes. The relevance of duration contingency for projects derives from the fact that most development schemes need to establish a firm date by which time the investment would start to generate returns. Any extensions beyond that date often presents distortions in the income flows associated with the project investment. Establishing level of such duration contingency should enable policy makers to appreciate the level of risk associated with the projects they promote.

SMALL PROJECTS SCHEDULE ESCALATION

Relatively, little attention has been given to the modelling of project characteristics and performance for medium and small schemes. Existing models that address project characteristics are based on records drawn mainly from large-scale projects, and for which data is readily accessible with occasional input with records from medium-sized projects. Cole (1991) and Popescu and Charoenngam (1995) provide examples that typify the large project orientation of schedule control in construction.

Early works in the control of project characteristics include developments by McCaffer (1975). This utilised regression techniques to establish a basis for predicting project costs from historical data. The main thrust of these developments was to identify a generic pattern of the value and time relationships for the different stages of a project. Subsequent developments focused on further exploration of the relationship between the value and duration of projects. This includes work undertaken by Kumaraswamy and Chan (1995), Walker (1995), Kaka and Price, (1991), Bromilow (1988). For example, using data from the Hong Kong construction industry, Kumaraswamy and Chan (1995) established that the estimation of project durations was often determined by a *rule of thumb* and *commercial and/or political considerations*. While this in itself is not necessarily wrong, it is important that such rules of thumb are derived from a rational basis. They further explored the relationship between the value and duration of the contracts that featured in their study and came up with mathematical models similar to those proposed earlier in other studies such as Kaka and Price, (1991), Bromilow (1988). Bromilow's earlier work had led to the development of cost-time profiles for projects, which was typified by the sigmoid curve. Kaka and Price (1991) demonstrated that a strong relationship existed between the construction period and final project value and this could be related by:

$$T = KC^{B} \tag{1}$$

where, T is the duration of construction period, C is the final project value, K is a constant describing the level of duration performance, and B is a constant describing how the duration performance is effected by the project size as measured by value. The model proposed by Kaka and Price (1991) gives values for *B* and *K* for public sector civil engineering works that were procured using fixed price contracts. Kumaraswamy and Chan (1995) also provide a good summary of the values for *B* and *K* for the proposed models that resulted from their studies. The strong correlation between cost and time attributes of construction projects was later confirmed in the work of Walker (1995).

More recently, Lee and Kyoo (1999) made use of a numerical approach to address the integration of the time and cost data sets for construction projects. They relied on the use of mathematical matrices, which are introduced to show the interrelationships between the time and cost data sets and to demonstrate their effect on each other. These interrelationships are exploited to solve the conflict that often arises from the differences between work breakdown structure and cost breakdown structure. This is achieved through several time and cost related matrix equations that are used for project planning or control. Feng et al. (1997) also employed a time-cost trade-off analysis to examine the relationships between project costs and duration. They utilised a genetic algorithm procedure for their analysis and argued that it enabled them to handle large volumes of data, the sort of which are associated with large projects.

These models provide a strong basis for employing one of the two variables of duration and cost as a predictor for the other. In the case of policy makers, project costs on small and medium schemes are determined by budgetary allocations, and this could be employed for one or more of several project options. As such the project budget provides the stable variable from which the duration of projects and associated levels of escalation that represent schedule contingency, can be estimated.

The next section of the paper provides a mathematical derivation of duration escalation for small and medium projects. The derived profile of escalation can be employed as part of the evaluation process and business case establishment required at the early stages of a project. This is based on the *non-linear* modelling of the project duration in a time cost plane.

To ensure that their model could be established with the linear regression approach, Kaka and Price (1991) as well as previous developers had to employ the log transformation to force the data into a linear relationship. Such transformation is a tacit acknowledged of the inadequacy of simple regression models to provide accurate representation of project cost-duration relationship. Kenley and Wilson (1986) for example had attributed lack of fit for transformed models to the *uniqueness* of each project and argued that this *uniqueness* resulted in a higher systematic error for any simple regression model developed with data from several projects. In particular, they concluded that forecasts of individual project cost and time profile are invalid when derived from a model that is established through simple regression of grouped data. Many relationships in construction operations and businesses often do not follow a straight line, and such transformation enables them to be modelled. The use of transformations however, has an effect on the predictive accuracy and efficient performance of the model that results from such developments. To overcome this potential inaccuracy inherent in transformed models Sohail and Edum-Fotwe (2000) utilised the non-linear regression approach for modelling the time cost relationships of small projects.

The general non-linear regression approach is a technique that fits a curve to a set of data. This is achieved with the use of a model equation that defines *-y-* as a function of *-x-* and one or more parameters. Details of how the general non-linear technique was employed to establish a time cost plane for small and medium projects can be obtained from Sohail and Edum-Fotwe (2000). Figure 1 presents a time-cost plane frame for small and medium infrastructure projects, and identifies three main regions for project schedule the boundaries of which are defined by the general exponential equation [2].

$$\text{Indexed project duration} = e^{\left(a + \frac{b}{x} + c \log x\right)} \qquad (2)$$

Where: x is the indexed cost of the project

The three regions provide the most likely scenarios of project schedule and cost performance for various types of schemes. An upper boundary demarcates the normal region from a region of exceptional project conditions with regard to schedule. The exceptional schedule conditions represent situations where a project experiences considerable schedule escalation without any commensurate cost escalation. An example of such a case is where a project is suspended due to either commercial or political demands, and later on re-activated.

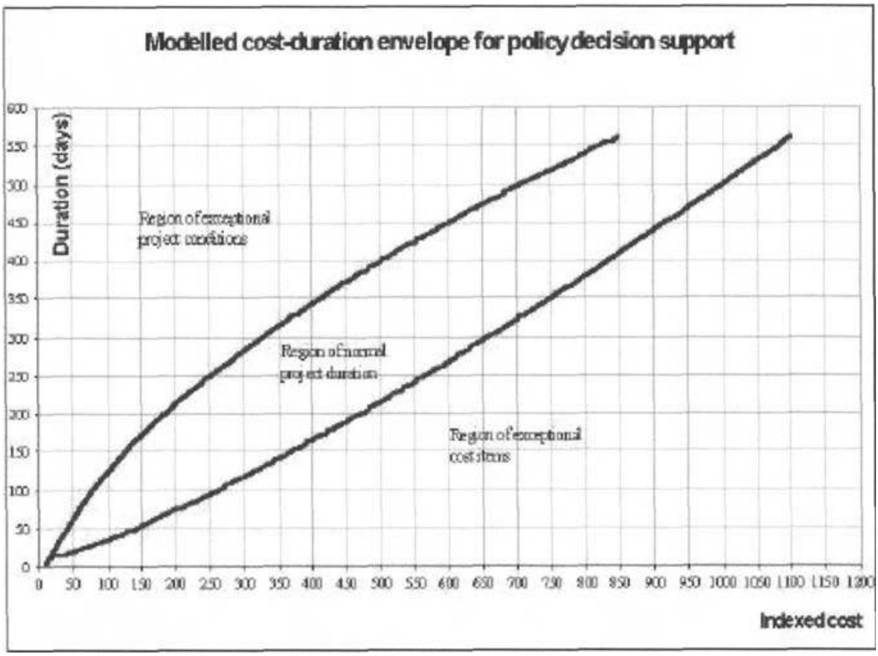

Figure 1. Time-cost plane for small infrastructure project (*Sohail & Edum-Fotwe, 2000*)

A lower boundary equally separates the normal region from one of exceptional cost items. The region of exceptional cost reflects projects where a higher proportion of cost than expected is accounted for by capital items or major plant installations. The region of normal project duration provides a range within which projects of similar size are expected to lie with regard to duration if they are not characterised by any exceptional circumstances. Equally it provides an indication of the degree of escalation that can be associated with projects of different sizes within the region of normal project conditions. Sohail and Edum-Fotwe (2000) have outlined the mathematical models that define the two boundaries. The general form of the expected escalation forms the thrust of this paper and has been derived by establishing the difference between the upper and lower boundaries of the normal region.

ESCALATION PROFILE OF SMALL PROJECTS

Figure 2 present the escalation profile associated with the region of normal project conditions. This was derived as follows:

Schedule escalation = Upper boundary – Lower boundary (3)

Based on the derivations of Sohail and Edum-Fotwe (2000) this yields:

Indexed schedule escalation = $y_{upper} - y_{lower}$ (4)

Resulting in, Indexed schedule escalation = $e^{\left(4.72-\frac{51.77}{x}-0.63\log x\right)}$ (5)

DISCUSSION OF ESCALATION PROFILE

The analysis presented in this paper has demonstrated that by relying on the implicit assumption of a relationship between cost and duration of projects, it is possible to model the scale of schedule escalation of small projects. This has been derived for infrastructure projects based on modelling work undertaken by previous authors. Figure 2 has presented the profile of the escalation for indexed projects up to 200 in size (indexed value). For a definition of the indexed value of small and medium projects, readers are referred to Sohail and Edum-Fotwe (2000). Similar profiles can be generated for all the different sizes of small and medium projects represented in the model proposed by Sohail and Edum-Fotwe (2000). The general form of the escalation profile is reflected by the exponential equation [5]. The profile provided suggests the following behaviour of escalation for the different sizes of small and medium infrastructure projects.

- Between the sizes of 13 and 40 (indexed value) projects in the normal range experience the steepest growth in schedule escalation.
- Between the sizes of 40 and 500 (indexed value) small and medium projects experience a reducing marginal growth in schedule escalation.
- Beyond the size of 500 (indexed value), projects begin to experience reduced levels of escalation although the tailing off is at a very slow rate.
- Projects of indexed size below 10 (indexed value) cannot be captured by the profile.

The tailing off of schedule escalation for projects over size 500 (indexed value) could be accounted for by their relatively larger size as projects of that size begin to reflect the characteristics of schemes that could qualify for medium to large-sized projects with exceptional circumstances.

The derived profile of schedule escalation presented in this study can provide a simple tool that can replace the current rule of thumb practice employed by policy makers for medium and small projects. This can be employed in establishing the expected level of schedule escalation for small and medium projects at the early stages when detailed design and analysis would not have been undertaken.

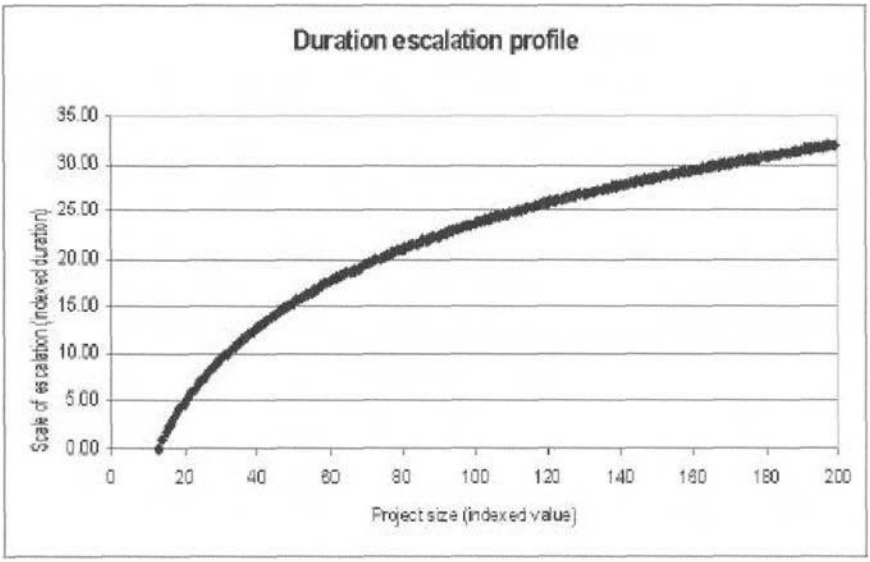

Figure 2. Escalation profile for small and medium infrastructure projects

This will provide an indication of the degree of risk of schedule escalation for this category of projects. Small projects are of such a nature that their size does not economically permit the detailed evaluation and estimating effort that forms an insignificant part of a larger project. As a result consideration of alternative project options are often not undertaken. The use of the escalation profile, particularly in its graphical form should allow the simulation of several scenarios for a project by policy makers. The profile can also be employed as a control mechanism for projects by providing the duration limits beyond, which the project becomes untenable or would be considered as one with exceptional conditions.

The schedule escalation profile can be of valuable assistance to small and medium AEC companies that usually undertake small and medium projects. Based on their historical project experience, a similar profile can be established and calibrated to the company's standards and requirements as a supplement to any business case and pre-design evaluation effort with obvious efficiency gains.

CONCLUSION

The relationship between project cost and duration of small and medium projects was employed to establish the profile of the duration escalation that occurred on infrastructure projects. The analysis resulted in three categories of escalation that occurred for small and medium projects: increasing escalation, reducing marginal escalation, and reducing escalation. It also presented indications that there is an inverse relationship between project size and level of escalation. The derived escalation profile can be generated in graphical form or as a table that policy makers can use to establish the level of normal escalation to anticipate as part of the feasibility of small projects. The derived escalation profile presented in this paper was based on projects from the infrastructure sub-sector. Similar profiles can be generated with data from projects for any other sub-sector. In this way, it should be possible to employ the profiles as a benchmark for managing project escalation on small and medium schemes.

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COMPARATIVE ANALYSIS OF THE PERFORMANCE OF BUILT ENVIRONMENT PROFESSIONALS IN SATISFYING CLIENTS' NEEDS AND REQUIREMENTS

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ABSTRACT

Globalisation has opened up numerous offshore investment opportunities for clients in the built environment. To retain them and remain in business, the construction industry and its professionals must strive to deliver higher levels of satisfaction or lose them to competitors in other countries offering more satisfactory procurement and investment outcomes. It is therefore necessary to appraise the efforts of professionals in meeting and satisfying the needs of their clients within a given locality with a view to identifying areas for improvement.

Consequently this paper presents a comparative analysis of the performance of professionals from clients' perspectives. The professionals involved in the study are architects, quantity surveyors, consulting engineers and construction/project managers who are fully registered and active members of their professional associations in South Africa. The client group consists of members of the prominent South African Property Owners Association.

The descriptive survey method was used in the study, involving qualitative data gathering through semi-structured interviews at the pilot survey stage, and quantitative surveys using questionnaires. Non-parametric statistics were used in the data analyses.

Clients' perceptions of the professionals' performance, aspects of professional services in which clients expect improvement and possible strategies for improving client satisfaction levels within the industry are presented.

INTRODUCTION

The advent of globalisation has opened up numerous off-sure investment opportunities for investors all over the world. For instance, in the UK property market, Baum and Schofield (1991) note that investment strategies are increasingly driven by globalisation. What this means is that investors no longer confine their investment to a defined national boundary, but are inclined to invest in any part of the global market, which holds prospects for more attractive returns on investment.

In the context of the construction industry, this development engenders stiff competition in the provision of services. Within any national boundary, the local service providers are therefore forced to compete for clients' attention and patronage with other global competitors. Client satisfaction, as the crucial variable influencing client investment or re-purchase intentions (Bearden and Teel, 1994), therefore becomes the determinant for the survival and sustenance of the construction industry and its service providers in any given country (Taylor and Baker, 1994).

It is in consideration of this development that Kotler (1997) asks, "How do companies compete in a global market place?" (p.63). A major part of the answer is a commitment to creating and retaining satisfied customers. Kotler further contends that companies can go about winning customers and outperforming competitors in a global market environment by doing a better job of meeting and satisfying customer needs.

Given the importance of client satisfaction and the fragmented nature of the construction industry, it may therefore be necessary to investigate and analyse clients' perceptions of the performance of the professions jointly and severally, with a view to identifying critical areas of responsibilities and aspects of services where improvements are expected, as well as possible strategies for improving the overall client satisfaction within the South African building industry.

CLIENT SATISFACTION

Context

For this study, 'client' is defined as the sponsor of the building process: the organisation or individual that initiates the building process and appoints the building team (Rowlinson, 1999).

Satisfaction is defined as a person's feelings of pleasure or disappointment resulting from comparing an outcome or a product's (physical or service) perceived performance in relation to his or her expectations (Kotler, 1997).

Satisfaction Components

Nkado and Mbachu (2001) identify the essential components of client satisfaction in the procurement process (see Figures 1 and 2) for two broad client categories: clients with long-term interests in the procured building (i.e. the investors and owner-occupiers), and clients with short-term interests (i.e. the developers) respectively.

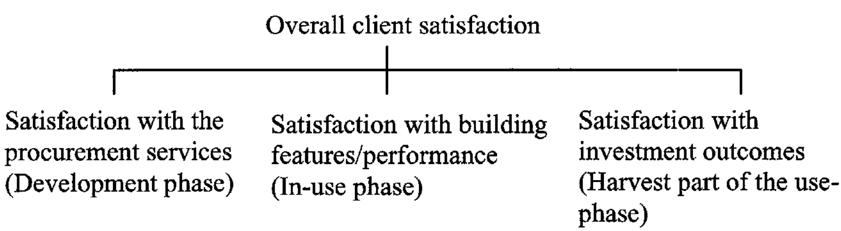


Figure 1 Components of Overall Satisfaction for Clients with Long-term Interests in the Procured Building (i.e. Investors and Owner-occupiers) (Adapted from Nkado and Mbachu, 2001).

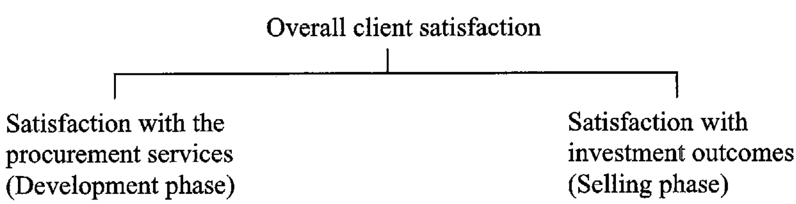


Figure 2 Components of Overall Satisfaction for Clients with Short-term Interests in the Procured Building (i.e. Developers) (Adapted from Nkado and Mbachu, 2001).

Satisfaction Measurement

In measuring satisfaction, Czepiel and Rosenberg (1976) are of the view that consumer satisfaction can be considered as a single overall evaluative response that represents a summary of subjective responses to many different facets. However, Handy and Ptaff (1975) opined that response to an overall satisfaction measurement only crudely assesses overall satisfaction, due to the fact that actual responses represent the person's immediate reaction to a complex situation, which may be in contrast to reality.

The satisfaction measurement approach adopted in this study draws on both Czepiel and Rosenberg (1976) and Handy and Ptaff (1975) approaches. The former was adopted in analysing clients' overview of the performance of the professions, while the latter was used in analysing clients views on the professionals' performance in the various service attributes, since this will help to pinpoint areas for improvement, which constitute one of the objectives of the study. Nkado and Mbachu (2001) provide a generic model for measuring overall satisfaction from a combination of facets or attributes of the service dimension being assessed:

$$S_g = \sum_{i=1}^{M} a_i S s_i \qquad (2.1)$$

$$S_o = \frac{1}{N} \sum_{i=1}^{N} S_{gi} \qquad (2.2)$$

Where:

S_g = Satisfaction level obtained from the services of a given professional group

a_i = Relative weight or importance index of an attribute of the professional service, considered important by the client

Ss_i = Satisfaction rating given by the client in respect of the professional group's performance in satisfying the i^{th} requirement or attribute.

M = Number of attributes of the professional group's services, which the client perceived to be relevant in line with his priorities

So = Overall satisfaction derived from the combined efforts of the professional groups

N = Number of key professional groups considered in the procurement process (i.e. four)

METHODOLOGY

The descriptive survey approach was adopted in the study. This comprised of qualitative data gathering at the pilot survey stage, during which non-structured interviews were conducted with convenience samples of clients and professionals in Johannesburg and Port Elizabeth cities of South Africa. Twelve directors or senior executives of private commercial property client organizations (four each of developers, investors and owner-occupiers) who agreed to participate in the interviews were approached. For the professionals, twelve principals or senior staff (three, each of architects, quantity surveyors, consulting engineers, and construction and project managers) participated in the interviews. Constructs established at the client interviews covered: (1) Client requirements or expectations from the four groups of professionals involved; and (2) Strategies for improving client satisfaction levels in the South African building industry. Constructs established at the interviews with professionals covered possible strategies for improving client satisfaction levels in the industry.

Constructs generated at the pilot interviews were used in the design of a questionnaire, which was subsequently pre-tested and administered in a postal census survey of the 223 members (as at February 2001) of the South African Property Owners Association (SAPOA) involved in property development and investment in South Africa. The data requested were: (1) clients' ratings of the levels of importance of the various requirements/expectations from each of the four groups of service providers, as identified during the pilot interview stages, and (2) clients' ratings of the levels of satisfaction delivered by the professionals for each of the requirements expected of a given professional group. A one-page questionnaire was similarly designed for the professionals to establish possible areas for improving client satisfaction levels within the industry. The fax medium was used for speedy administration of the questionnaire.

Due to the huge financial costs involved in large scale questionnaire survey for representative sampling needed to mitigate usual low response rates reported in the industry (Nkado, 1999), no attempt was made to obtain representative samples of the professional groups. A convenience sampling method was adopted, during which forty professionals, comprising ten members of each of the four groups, were approached, excluding those who participated in the qualitative interviews. The selection was on the basis of practitioners' willingness to participate in the structured questionnaire survey. The questionnaire sought to establish the respondents' views on the levels of importance of the strategies suggested for improving client satisfaction in the industry. Responses obtained from the professionals were therefore not representative of the views of the population of South African construction professionals. However a wider study is currently underway.

SURVEY RESULTS, DATA PRESENTATION AND ANALYSE

Survey Results

Of the 223 clients surveyed, fifty-three responded; 48 of these responses were fully usable. This represents an effective 21.5% response rate. Categorization of the respondents' organizations revealed that nine (18.8%) are involved with property developing only; four (8.3%) are owner-occupiers; fifteen (31.2%) are concerned with property and portfolio investment businesses, while twenty (41.7%) are exposed to both property development and investment. The responses therefore mainly reflected the views of private sector commercial property clients who are engaged in property development and investment.

A profile of the status of the respondents showed that thirteen (27.1%) are directors; twenty-five (52.1%) are senior executives, while ten (20.8%) are in the middle management cadre. The respondents have over ten years of property-dealing experience. It is felt that their responses are based on experience and sound judgment, and are therefore reliable.

Clients' Perceptions of Satisfaction Levels Delivered by the Professions

Clients were asked in the structured questionnaire to give an overview of the performance of each of the four professional groups in meeting their needs or requirements by rating on a five-point Likert scale: 1 (dissatisfied, D); 2 (little satisfied, LS); 3 (somewhat satisfied, SS); 4 (Just satisfied, JS) and 5 (very satisfied, VS). A summary of their responses are shown in Table 1.

In the table, professional groups (PG) consist of quantity surveyors (QS); architects (ARC); consulting engineers (CE); construction and project managers (C/P); and a combination of all the professional groups (ALL).

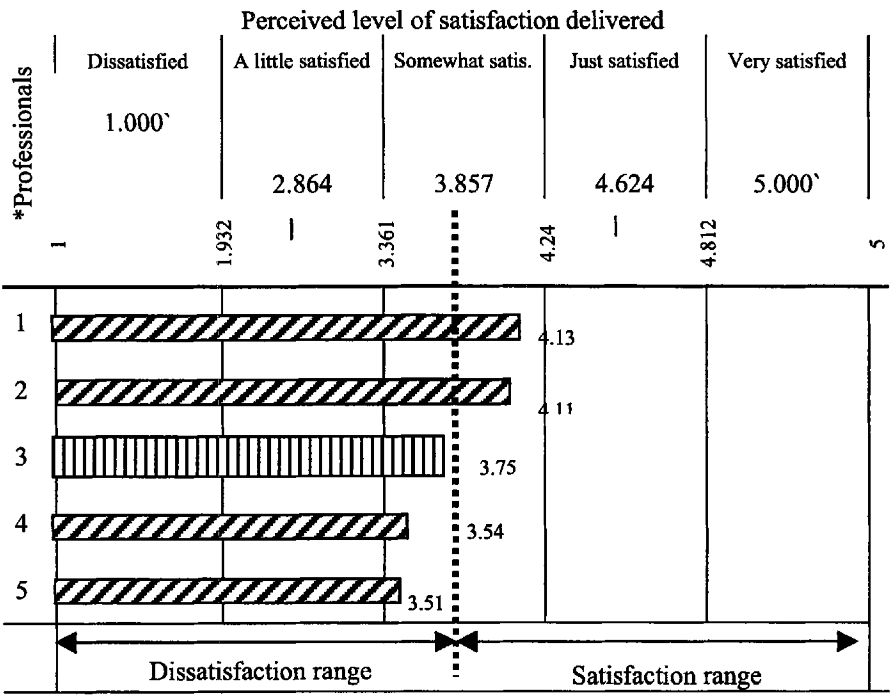
Table 1 Analysis of Clients' Views on Satisfaction Levels Delivered by the Professions

	Clients' responses to levels of satisfaction							
	VS	JS	SS	LS	D			
	5	4.624	3.857	2.864	1			
PG	%	%	%	%	%	TR	PI	RPI
QS	10.42	43.75	33.33	8.333	4.1667	48	4.1098	0.269
ARC	6.25	14.58	45.83	22.92	10.417	48	3.5151	0.23
CE	14.89	38.3	31.91	12.77	2.1277	47	4.1334	0.27
C/P	0	16.67	54.17	20.83	8.3333	48	3.5399	0.231
							15.298	1
ALL	8.333	20.83	50	12.5	8.3333	48	3.7498	

*TR = total responses for each group; PI = performance index (for each group) = $\sum_{i=1}^{5}(P_iR_i)$

Where: P_i = point rating (1-5) as satisfaction level delivered by a group; R_i = % responses to i^{th} level of satisfaction for a given group.

RPI = relative performance index for a given service group, k; $= PI / \{\sum_{k=1}^{4} PI_k\}$



*Professional groups: (1) Consulting engineers; (2) Quantity surveyors; (3) All professional groups combined; (4) Construction/project managers; (5) Architects.

Figure 3 Clients' Perceptions of Satisfaction Levels Delivered by the Professions.

Re-scaling

Before carrying out statistical operations on the ordinal data (ratings), correspondence analysis was first used to re-scale the five-point Likert scale responses from ordinal to interval data as suggested by Nkado (1999). Bendixen and Sandler (1995) document this procedure, arguing that it is essential for statistical manipulation and interpretation of raw ordinal data.

The conversion of the Likert scale was performed separately for each set of ratings made by the respondents. Subsequently, the performance (PI) and relative performance (RPI) indices were computed in Table 1 using methods suggested by Nkado and Mbachu (2001). The results of the analysis are schematically illustrated in Figure 3.

Analysis of Aspects of Professional Services Requiring Improvement

Clients were asked to rate the levels of importance of client requirements or expectations from the various professional groups. They were also asked to rate the levels of performance of a given professional group in satisfying each of the requirements. Following Handy and Ptaff's (1975) approach, satisfaction level delivered by each professional group was measured by considering satisfaction level in each attribute or facet of the service delivery as shown in Equation (2.1). This approach was adopted to pinpoint the aspects of each professional group's services, which, from the perception of the client, fell below expectations. Assessment of the satisfaction level delivered by the combined efforts of the professionals was subsequently determined using Equation (2.2).

Prior to the analysis, the rating scale for each set of data was converted from ordinal to interval data as previously described. The importance index (II) for each set of requirement was computed to identify those requirements which clients deem important. The relative importance index (RII) was also computed to reveal the scale of preference or priority level accorded to the requirements by clients. Satisfaction score (SS) (denoting level of satisfaction delivered in each of the important client requirements) was subsequently computed. This computation draws on the approach used by Nkado and Mbachu (2001) and involved multiplying the satisfaction index (product of rating point and percentage responses) with the relative importance index of each important requirement. By fitting the SS computed for each professional group into the re-scaled interval ranges computed for the data set, values which were below the re-scaled 'somewhat satisfied' point for the data set revealed aspects of the key client requirements in which clients felt unsatisfied. These were consequently highlighted as areas for improvement.

Criticality Index (CI)

In order to prioritise the identified areas for improvement, the concept of a Criticality Index was used. The concept was developed on the premise that the extent of the need for improvement in a given attribute of professional service is dependent upon the level of importance attached to it by clients and the perceived level of satisfaction currently delivered by the professional group concerned. Thus the criticality for improvement increases with the level of importance (as indicated by the importance index) and decreases with the satisfaction level currently delivered (as reflected by the performance index). This means that the need for improvement in a high priority service attribute would not be critical if the professionals concerned are already delivering high levels of satisfaction. However, the reverse is the case if satisfaction level is perceived to be low. Consequently the CI is computed as follows:

$$CI = \frac{II}{PI} \qquad (4.1)$$

Where: CI = Criticality index; II = Importance index; PI = Performance index.

Summary of Clients' Requirements, Groups' Performance and Areas for Improvement

Results of the analyses of clients' priorities and professionals' performance areas for improvement are shown in Tables 2. The requirements and expectations are listed in order of priority or level of importance as indicated by the value of the importance index (II) computed for the requirement.

For the quantity surveying services (Table 2), the requirements are prioritised as follows (starting with the topmost priority): 1) Accurate and reliable cost and budget estimates, feasibility/viability and risk assessments; 2) Efficient performance of duties as per terms and conditions of appointment/engagement; 3) Service efficiency (timely job execution and comprehensiveness of cost information); 4) Demonstration of competency (expertise and experience) for the job; 5) Ability to foresee and budget reasonably for potential causes of cost escalations.

Table 2 Summary of Clients' Requirements, Professional Performance and Areas for Improvement

{*II = Importance index; Remarks (JI = Just important; SI = Somewhat important); Ss = Satisfaction score; Range = Operating re-scaled range; CI = Criticality index; VS = Very satisfactory; JS = Just satisfactory; SS = Somewhat satisfactory; LS = Little satisfactory

Clients' requirements (in order of importance)	Level of importance	Operating range				Satisfaction level	Operating range				
	*II	Lower	Middle	Upper	Remark	*Ss	Lower	Middle	Upper	Remark	CI
a) Quantity surveying services:											
1)	3.87	3.18	3.76	4.38	JI	2.76	2.19	2.56	3.09	JS	1.4
2)	3.85	3.18	3.76	4.38	JI	3.20	3.09	3.62	4.31	VS	1.2
3)	3.60	3.18	3.76	4.38	JI	2.90	2.19	2.56	3.09	JS	1.2
4)	3.35	3.18	3.76	4.38	JI	3.33	3.09	3.62	4.31	VS	1
5)	2.97	2.27	2.60	3.18	SI	2.38	2.19	2.56	3.09	JS	1.2
Satisfaction level based on multi-attribute evaluation:						2.93	2.19	2.56	3.09	JS	
b) Architectural services:											
1)	4.48	3.66	4.30	4.65	JI	3.01	2.60	3.10	3.75	SS	1.5
2)	4.30	3.66	4.30	4.65	JI	3.22	2.60	3.10	3.75	SS	1.3
3)	4.13	3.66	4.30	4.65	JI	3.35	2.60	3.10	3.75	SS	1.2
4)	3.82	3.66	4.30	4.65	JI	2.75	2.60	3.10	3.75	SS	1.4
5)	3.42	2.67	3.01	3.66	SI	2.88	2.60	3.10	3.75	SS	1.2
6)	3.00	2.67	3.01	3.66	SI	3.40	2.60	3.10	3.75	SS	0.9
Satisfaction level based on multi-attribute evaluation:						3.10	2.60	3.10	3.75	SS	
c) Consulting engineering services:											
1)	4.28	3.37	3.81	4.40	JI	2.29	1.39	1.78	2.40	LS	1.9
2)	3.98	3.37	3.81	4.40	JI	3.05	2.40	3.02	3.62	SS	1.3
3)	3.74	3.37	3.81	4.40	JI	3.69	3.62	4.23	4.61	JS	1
4)	3.51	3.37	3.81	4.40	JI	2.57	2.40	3.02	3.62	SS	1.4
5)	3.18	2.61	2.94	3.37	SI	2.27	1.39	1.78	2.40	LS	1.4
6)	2.89	2.61	2.94	3.37	SI	3.21	2.40	3.02	3.62	SS	0.9

Satisfaction level based on multi-attribute evaluation:	2.84	2.40	3.02	3.62	SS

For architectural services (Table 2), the requirements are prioritised as follows: 1) Delivery to be timely, detailed and comprehensive; 2) Flexibility in design (to accommodate changes with minimal cost implications); 3) Efficient performance of duties as per terms and conditions of appointment; 4) Optimal, workable and error-free designs & detailing; 5) Design tailored to suit client's budget, yet adequately address client's main needs; 6) Aesthetic appeal (beauty in design and concepts).

Table 2 (continued)

	Level of importance					Level of satisfaction					
Clients requirements	*II	Lower	Middle	Upper	Remarks	*Ss	Lower	Middle	Upper	Remarks	CI
d) Construction/project management services:											
1)	4.86	4.44	4.81	4.90	JI	1.77	1.55	2.10	2.79	LS	2.7
2)	4.81	4.44	4.81	4.90	JI	2.19	1.55	2.10	2.79	LS	2.2
3)	4.61	4.44	4.81	4.90	JI	2.41	1.55	2.10	2.79	LS	1.9
4)	4.46	4.44	4.81	4.90	JI	1.73	1.55	2.10	2.79	LS	2.6
5)	4.04	3.40	4.07	4.44	SI	2.62	1.55	2.10	2.79	LS	1.5
6)	3.88	3.40	4.07	4.44	SI	2.66	1.55	2.10	2.79	LS	1.5
Satisfaction level based on multi-attribute evaluation:						2.21	1.55	2.10	2.79	LS	

In Table 2, clients' requirements or expectations from the services of the engineers are prioritised as follows: 1) Delivery to be timely, detailed and comprehensive; 2) Safe and economical design; 3) Efficient performance of duties as per terms and conditions of appointment; 4) Sustainability and flexibility in design and construction; 5) Workable and error-free designs and detailing; 6) Functional and durable design and construction.

In the same Table 2, clients requirements from the services of the construction and project managers are prioritised as follows: 1) Delivery within time, quality and cost targets; 2) Technical and managerial competences and experience; 3) Team work and efficient co-ordination of all the services to achieve desired goals; 4) Manage client's changes efficiently (with minimal cost implications); 5) Efficient/unbiased communication of project objectives to all parties; 6) Efficient performance of duties as per terms and conditions of appointment.

Strategies for Achieving Higher Client Satisfaction Levels in the Industry

At the pilot interviews, all the twenty-four interviewees (clients and professionals) concurred that the most appropriate strategies for achieving higher levels of client satisfaction in the South African would involve clients and professionals living up to their mutual responsibility in the procurement process. Professionals disclosed expected areas of clients' responsibilities for successful project outcomes, while clients highlighted those of the professionals. These constructs were incorporated into the survey questionnaire.

The ratings given by clients and professionals on the identified areas of mutual responsibility are shown in Table 3. The importance index (II) and relative importance index (RII) are also computed in Table 3 to rank the strategies in their order of importance.

The areas of clients' responsibility as itemised in Table 3 are: 1) Reasonable expectations; 2) Seeking professional advice in investment decisions; 3) Disclosing all motives for investment at the outset to, and being prepared to consider suggestions from, the project team; 4) Fulfilment of contractual obligations as and when due; 5) Considering tenant profile and rent or lease renewal intentions before embarking on procurement; 6) Budgeting sufficient time and funds for detailed feasibility; 7) Striving to cultivate synergy amongst project team members, through strong emphases on teamwork, equality and fairness; 8) Assessment of levels of similar developments in the area before investing; 9) Proper briefing; 10) Employment of specialists in all critical aspects of work.

Areas of professionals' responsibility as itemised in Table 3 include: 1) Computerisation of services with a view to adapting more efficiently to changes and timely delivery; 2) Customer-oriented service approach; 3) Greater emphasis on teamwork and synergy; 4) Efficient discharge of contractual obligations; 5) Concentration on areas of core competences; 6) Avoiding profiteering tendencies and minimizing contractual claims

Table 3 Summary of Strategies for Improving Client Satisfaction Levels

*II_p; II_c = Importance indices computed from professionals' and clients' sample data respectively; REM = Remarks on the re-scaled interval range for the data set into which the important index falls: NI = Not important; LI =Of Little importance; SI = Somewhat important; JI = Just important VI = Very important

Strategy	Points of view: Professionals *II_p	Rank	REM	Clients *II_c	Rank	REM	Consensus
A) Areas of clients' responsibility							
1)	4.66	1	JI	2.93	7	JI	
2)	4.47	4	JI	2.59	9	JI	
3)	4.24	6	JI	2.29	10	SI	
4)	4.6	2	JI	3.6	2	JI	X
5)	3.21	9	SI	3.47	3	JI	
6)	4.36	5	JI	2.99	6	JI	X
7)	3.76	8	SI	2.85	8	JI	X
8)	3.09	10	LI	3.32	4	JI	
9)	4.55	3	JI	3.74	1	JI	
10)	4.07	7	JI	3.25	5	JI	
Spearman's rank correlation coefficient, R =					0.042		
Rcritical (at 0.05 level of significance; n = 10) =					0.68		
Result: R < Rc (i.e. No significant correlation exists between both sets of ranks)							
B) Areas of professionals' responsibility							
1)	3.61	4	SI	3.17	5	JI	X
2)	4.09	3	JI	3.27	4	JI	X
3)	4.27	1	JI	2.75	6	JI	
4)	4.2	2	JI	3.58	1	JI	X
5)	3.58	5	SI	3.49	2	JI	
6)	3.06	6	SI	3.42	3	JI	
Spearman's rank correlation coefficient, R =					-0.314		
Rcritical (at 0.05 level of significance; n = 6) =					0.9		
Result: R < Rc (i.e. No significant correlation exists between both sets of ranks)							

DISCUSSION OF RESULTS

Analysis of clients' responses to levels of satisfaction delivered by the four groups of professionals was done in Table 1. Results, plotted in Figure 3, showed that consulting engineers and quantity surveyors were perceived to deliver slightly above the minimum satisfaction threshold (i.e. delivering 'somewhat satisfactory' performance levels). Though the satisfaction level achieved fell slightly below the 'just satisfied' rating, the performance of these groups appeared to be better than those of the architects, and construction and project managers, whose performance levels fell short of the minimum satisfaction threshold.

In terms of comparative performance assessment, the consulting engineers were perceived to perform best among the four groups of professionals involved in the study. Architects on the other hand were perceived to perform least on the performance continuum. Overall, a joint assessment of the four groups of professionals fell below the minimum satisfaction level. Obviously the perceived poor performance of the architects, and construction and project managers might have diluted the satisfactory performance ratings of the engineers and quantity surveyors when the clients made a joint assessment of the groups.

Several factors could account for the clients' poor performance rating of the architects: in the traditional procurement process, the architect is seen as the leader of the building team (Rougvie, 1987). Clients in the South African building industry still prefer the traditional procurement option (Bowen *et al.,* 1997). With the rising spate of client dissatisfaction within the South African building industry as alleged by Bowen *et al.* (1997), it appears that most clients would place the blame for non-performance on the architects as the leaders of the building team in the traditional procurement system.

The computed relative importance indices were used in prioritising clients' requirements from the services of professionals. The results were summarised in Table 2. The criticality index (CI) served to prioritise the areas for improvement by taking into consideration the level of importance of a service attribute and the level of satisfaction currently delivered by the professional group, as perceived by clients. An inspection of the CI indices reveals that accuracy and reliability of cost or budget estimates, feasibility or viability, and risk assessments are clients' topmost priorities in their expectations from the services of quantity surveyors. This corroborates the argument that clients desire cost certainty (Rougvie, 1987). This could partly account for the continual adoption of the traditional procurement approach, which has this combination of attributes as one of its key selling points (Turner, 1990). Also clients' emphasis on timely, detailed and comprehensive service delivery in their requirements and expectations from the services of architects and engineers could have arisen from the widely held view that one of the factors contributing to time overruns in the industry is delay caused by insufficient design information (or lack of it) and detailing errors (Rougvie, 1987). These have also led to numerous abortive works on site with associated cost overruns. Perhaps it is time that architects rethink the practice of absolving themselves of blame or consequences arising from detailing errors by the use of caveats on working drawings. From the services of construction and project managers, clients' topmost expectation of delivery within time, cost and quality targets concurs with the literature (e.g. Turner, 1990).

Clients' suggestions on the aspects of the professionals' services for improvement for satisfactory project outcomes were analysed in Table 3. Similar suggestions made by the professionals in respect of clients' responsibilities were also analysed in Table 3. Correlation test results in Table 3 show that clients' views on priority levels of the areas for improvement diverge significantly from corresponding views of professionals.

However, analysis of areas of consensus (Table 3) shows that both parties agree that striving to cultivate synergy amongst project team members and fulfilment of contractual obligations as and when due, are clients' crucial areas of responsibility for achieving successful project outcomes. Clients and professionals also concur that computerisation of services; customer-oriented service approach and efficient discharge of contractual obligations by professionals will make a difference in satisfaction outcomes.

CONCLUSION

From the foregoing investigations and analyses, it can be concluded that on a comparative basis, clients ranked topmost, the consulting engineers performance in meeting their requirements in the procurement process, with architects being the last in the performance continuum.

Overall, clients are dissatisfied with the services of professionals, though only 'somewhat' satisfied with the services of engineers and quantity surveyors at the level of individual professionals. Clients' most preferred improvement in the services of the professionals include the ability to foresee and budget reasonably for potential causes of cost escalations by quantity surveyors; optimal, workable and error-free designs and detailing by architects; timely, detailed and comprehensive delivery of design information by consulting engineers; and efficient management of clients' changes (with minimal cost implications) by construction/project managers.

There is consensus amongst clients and professionals on the latter discharging their contractual obligations efficiently and the former ensuring proper briefing as the two most viable and sustainable strategies for improving client satisfaction levels in the South African building industry.

The criticality index (CI) could be use to prioritise areas of services for improvement, taking into account levels of importance and satisfaction currently delivered by the service provider.

It should be noted that the above conclusions are generic in nature as they apply to collective views on the subject. It is proposed that needs and satisfaction issues, being highly subjective, should be better approached in practice by applying the methodology developed in this study to individual circumstances.

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ENHANCING THE COMPETITIVENESS OF QUANTITY SURVEYING SERVICES: A *JOHARI*-BASED ANALYSIS

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ABSTRACT

Competitiveness of professional services is competency driven. Competitiveness is predicated on relevance to, and satisfaction of, client needs and the ability to create innovative services that add value to the organisation and management of construction processes. This paper investigates how building economists or quantity surveyors can enhance the competitiveness of their services in the building industry.

The paper presents the outcome of research which was based on the premise that effective communication is critical and achievable from a combination of internal disclosure and external feedback using the Johari analysis framework. The research methodology includes the review of related literature, fieldwork comprising interviews and postal questionnaires administered to random samples of architects, engineers and quantity surveyors in South Africa, and analysis of qualitative and quantitative data using appropriate statistical and other techniques.

The views of quantity surveyors on competencies required by the profession for business success (disclosure) are compared with the views of other users of quantity surveying services, namely architects and engineers (feedback). The results are discussed in the context of more effective positioning of quantity surveying services and a methodology for auditing the services of other built environment professions.

INTRODUCTION

Quantity surveying as a professional service originated in the UK in 1785 (Seeley, 1979) but quantity surveying services in construction date back much earlier to the time of the Egyptian pyramids (Thompson, 1968; Gregory, 1971). The professional quantity surveyor has emerged as a respected financial specialist and adviser in the construction industry of those countries where his expertise is recognised. However, as both the nature of construction and the needs of clients have evolved over time, so the critical review of the roles and responsibilities of the quantity surveyor has become increasingly vital for continuing relevance of services and future success (Nkado & Meyer, 2001).

The ability of the quantity surveying profession to meet changing client needs and to grow the market for quantity surveying services depends on the knowledge base of the profession. Prokesch (1997) advocates that building and leveraging knowledge is the key to success in this age of globalisation, while Male (1990) opines that knowledge is an important power base for professions generally. Competencies are the manifestation of knowledge acquired through education, training and self-learning. Wisher (1994) insists that competencies provide a common cultural thread, a language for success, a framework for thinking about excellence and a way of communicating the future.

Competent quantity surveyors must have a range of skills, knowledge and understanding which can be applied in a range of contexts and organisations (Hassall, Dunlop & Lewis, 1996). Yet critical issues for continued growth of the quantity surveying profession include addressing the relevance and level of awareness of the profession's services in the built environment and increasing the range of business opportunities. These issues can be addressed by a competency-based review of the profession (Mole, Plant & Salaman, 1993). Such a review would establish a profession-wide awareness of, and responsibility for developing the key competencies required for the continuing relevance and survival of the quantity surveying profession.

This paper investigates how building economists or quantity surveyors can enhance the competitiveness of their services in the building industry from a *Johari*-analysis framework using a combination of internal disclosure and external feedback.

JOHARI ANALYSIS

One way of updating and leveraging the profession's knowledge base is to ensure that the constituent skills, abilities and values of the profession are subjected to periodic internal auditing by quantity surveying professionals to highlight critically important competencies. The proficiency levels of practitioners in these competencies can then be assessed with a view to instituting remedial measures where necessary. Such an outcome would yield a helpful disclosure to the profession.

A complementary approach is to assess end-users' perceptions of the important competencies required to meet user needs, as well as users' perceptions of current proficiency levels among practitioners. This complementary input would serve as essential feedback to the profession. The combination of disclosure and feedback can be depicted in a "Johari"-type analysis (Fig. 1). The need for regular audit of the competencies of the QS profession is perhaps underscored by Thompson's (1968) view that advancement of professional knowledge and skill would demonstrate to, and enhance the perception among, clients that practitioners were continually improving the quality of the services they offered.

According to Robbins (1998), proponents of the Johari window imply that perceptual accuracy and communication would be improved if the size of the "Public" window were expanded by increasing self-disclosure and by listening to feedback from others even if the feedback is unflattering. In this paper, the "self-disclosure" by quantity surveyors on the importance of competencies and levels of practitioners' proficiency is contrasted with the "feedback" from engineers and architects.

The most authoritative record of competencies required of quantity surveyors is contained in RICS (1998) under three categories of basic, core and optional competencies (see Table 1). This study goes further by establishing the future importance ratings of the competencies considered relevant in the South African context and by comparing these ratings with perceived current proficiency levels in practice.

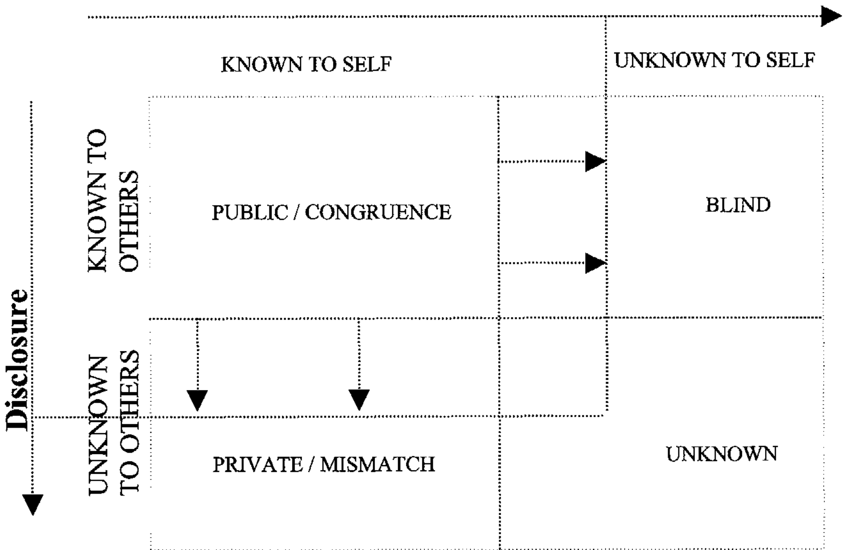

Figure 1 Johari Window showing effects of feedback & disclosure

Table 1: Competency headings for professional quantity surveyors

Basic competencies	Core competencies	Optional competencies
• Personal & Interpersonal skills • Business skills • Data, Information and Information Technology • Professional Practice • Law • Measurement • Mapping	• Construction Contract Practice • Construction Technology & Environmental Services • Economics of Construction • Procurement and Financial Management	• Arbitration & Other Dispute Resolution Procedures • Development Appraisal • Facilities Management • Insolvency • Insurance • Project Management • Property Investment Funding • Research Methodologies & Techniques • Taxation Allowances & Grants • Valuation

Source: The Royal Institution of Chartered Surveyors (1998)

METHODOLOGY

In a primary descriptive survey by Nkado (1999), generic competencies of quantity surveyors were identified from the literature and from the results of depth interviews of a convenience sample of five experienced (over ten years in practice) and five younger practitioners (less than ten years experience) in the Greater Johannesburg area of South Africa. A pre-tested questionnaire was subsequently designed to obtain respondents' Likert scale ratings of current and future importance, and current proficiency levels in the use of the 23 competencies identified by three or more interviewees. The questionnaire contained all the basic and core competencies of Table 1, six out of ten optional competencies and six other competencies identified as uniquely relevant in the South African context. The structured questionnaire was administered nation-wide by post on a stratified random sample of 600 registered and 'in-training' quantity surveyors.

In a complementary survey by Crafford (2001), a convenience sample of three architects and nine consulting engineers in the Eastern Cape and Western Cape Provinces of South Africa were interviewed concerning the competencies required by quantity surveyors. The competencies identified in the primary research were presented for vetting at the scheduled interviews. Interviewees were requested to indicate whether they agreed with the outcomes associated with the competency headings, and to suggest additional outcomes or new competencies. Subsequently, a pre-tested questionnaire was designed in the format of the primary survey incorporating all 23 competencies and two additional competencies identified as relevant by the interviewees (see the Appendix). The resulting questionnaire was administered by post to a random sample of 360 consulting engineers and 440 architects in South Africa.

RESULTS AND DISCUSSION

The number of responses for the primary survey was 150, a response rate of 25%. Although low and potentially exposing the results to bias, the response rate fell within the range achieved by similar postal surveys of professional quantity surveyors (Atkin *et al.*, 1993; Procter, 1997). A chi-square analysis of the known demographic profiles of the survey sample *versus* the respondents' profiles revealed no bias in the respondent sample relative to the non-respondents, apart from a significant under-representation of surveyors-in-training. The number of responses for the complementary survey was 134, a response rate of 17%. This was again much lower than expected but preliminary analyses revealed no overt evidence of bias in the respondent sample.

Re-scaling

The ordinal Likert scale ratings were re-scaled to interval data using correspondence analysis (Bendixen & Sandler, 1995; Nkado & Meyer, 2001), thereby permitting parametric manipulation of the data. A researcher is on indefensible ground when assuming that Thurstone or Likert scales behave in an interval fashion. Nevertheless, this assumption is so commonly made that it is seldom even stated in published articles (Bendixen and Sandler, 1995). Re-scaling is an explanatory, rather than causal analysis as the re-scaled values are for the full set of observations over all the constructs that are rated. This limitation means that re-scaling does not indicate how each respondent used the scale for each statement that was rated. According to Bendixen and Sandler (1995), in some "instances, the subsequent analyses produce results that are almost identical to those obtained when the assumption that the original ordinal data behaved in an interval fashion was made or that the analytic techniques used was sufficiently robust. However, in equally as many instances, the interpretation of subsequent analyses was 'cleaner', easier and more precise." The re-scaled ratings were analysed to obtain rankings of current importance, future importance and current proficiency levels of the competencies of quantity surveyors, from the perspectives of quantity surveyors, architects and engineers (Nkado, 1999; Crafford, 2001)

Johari window in relation to results

According to Robbins (1998) the Johari window (Fig. 1) works on the principle that mutual understanding improves perceptual accuracy. The Johari "Public" window was widened by the results of the primary survey which was based on 'disclosure' from quantity surveyors (Nkado, 1999). However, it only widened in the direction of the "Blind" area. The result of the complementary survey of the design team helps to expose both the "Mismatch" and "Unknown" areas of the Johari window (Fig. 1). According to Robbins (1998) the "Unknown" area of the Johari window includes feelings, experience and information that neither the subject nor others are aware of. To gain a better impression of the difference in perception between quantity surveyors and the design team, the ranked competencies are placed in the Johari window (Tables 2, 3 and 4). Competencies with absolute difference in ranking of more than three positions are placed in the "Mismatch" area. The competencies which were identified uniquely by the design team are placed in the "Blind" area. Competencies that do not differ by more than three rank positions are placed in the "Congruence" area. For simplicity, ranks, rather than aggregate percentage ratings, are used for this comparison. In the tables, the figures in brackets are the aggregate rankings of the competencies; the first ranking is that of architects and engineers while the second is the ranking of quantity surveyors.

Table 2 Johari representation of current importance ratings of competencies

Congruence	**Blind**
• Construction contract practice (2, 4) • Economics of construction (3, 3) • Computer literacy and IT (4, 1) • Procurement and financial mgt (5, 2) • Professional practice (6, 6) • Advanced financial management (8, 10) • Personal & interpersonal skills (9, 8) • Development appraisal (10, 9) • Skills in managing a business unit (12, 14) • Law (14, 17) • Project management (15, 12) • Management of joint QS appointment (17, 19) • Arbitration and other dispute resolution procedures (19, 16) • Mapping (20, 20) • Macro-economic perspectives (21, 21) • Research methodologies and techniques (24, 23) • Facilities management (25, 22)	• Structural knowledge (22, -) • Expert witness (23, -)
Mismatch	**Unknown**
• Measurement (1, 5) • Skills to work with emerging contractors (7, 13) • Construction tech. and environ. (11, 15) • Property investment funding (13, 18) • Leadership and general mgt. (16, 11) • Marketing (18, 7)	

Tables 2 and 4 suggest substantial congruence of views on current importance and proficiency levels of competencies between quantity surveyors and the design team, represented in this study by architects and consulting engineers. The public windows of both Tables cover 68% and 72% respectively of the rated competencies, with 24% and 20% respectively of competencies in the mismatch window. This probably illustrates a high level of historical understanding of the work of the quantity surveyor, and quantity surveyors' interaction with other members of the design team.

In contrast, Table 3 reveals only 52% congruence and as much as 40% mismatch in the future importance ratings of the competencies. This suggests that architects and engineers do not fully share or endorse the vision of quantity surveyors on areas of future strength for the quantity surveying profession. Although the Spearman's rank correlation coefficient test does not indicate significant disagreement in the overall rankings of the defined competencies, the deduction is clearly different for competencies in the mismatch window. At the level of individual competencies of future importance, a notable finding emerges: architects and engineers appear to anticipate that quantity surveyors would strengthen their IT-driven technical competencies in measurement and construction contract practice. Quantity surveyors, however, clearly anticipate that the future of the profession would lie in management-orientated competencies of project management, marketing, personal and interpersonal skills, leadership and general management. This contextual mismatch of feedback and disclosure raises an important cautionary note to quantity surveyors to attempt to share increased awareness of the future repositioning of their professional expertise among a wide spectrum of built environment professionals and construction clients.

Table 3 Johari representation of future importance rating of competencies

Congruence	**Blind**
• Computer literacy and IT (1, 1) • Economics of construction (2, 3) • Procurement and financial mgt (5, 2) • Development appraisal (7, 10) • Professional practice (8, 11) • Advanced financial management (9, 7) • Skills in managing a business unit (11, 12) • Law (16, 16) • Macro-economic perspectives (19, 19) • Arbitration & other dispute resolution procedures (20, 17) • Mapping (21, 22) • Facilities management (23, 20) • Research methodologies and techniques (24, 23)	• Structural knowledge (22, -) • Expert witness (25, -)
Mismatch	**Unknown**
• Measurement (3, 15) • Construction contract practice (4, 9) • Skills to work with emerging contractors (6, 12) • Personal & interpersonal skills (10, 6) • Construction tech. and environ. (12, 18) • Management of joint QS appointment (13, 21) • Property investment funding (14, 8) • Marketing (15, 5) • Project management (17, 4) • Leadership and general mgt. (18, 13)	

Table 4 Johari representation of the rating of QS proficiency levels in competencies

Congruence	Blind
• Measurement (1, 1) • Procurement and financial mgt (2, 2) • Construction contract practice (3, 4) • Computer literacy and IT (4, 6) • Professional practice (5, 3) • Economics of construction (6, 5) • Development appraisal (7, 9) • Personal & interpersonal skills (9, 8) • Construction tech. and environ. (10, 10) • Law (13, 15) • Leadership and general mgt. (14, 11) • Property investment funding (15, 18) • Project management (17, 14) • Arbitration & other dispute resolution procedures (19, 17) • Skills to work with emerging contractors (21, 19) • Macro-economic perspectives (22, 21) • Facilities management (23, 22) • Research methodologies and techniques (25, 23)	• Expert witness (20, -) • Structural knowledge (24, -)
Mismatch	**Unknown**
• Skills in managing a business unit (8, 12) • Advanced financial management (11, 20) • Management of joint QS appointment (12, 16) • Mapping (16, 7) • Marketing (18, 13)	

CONCLUSION

In disclosing their professional competencies, quantity surveyors in South Africa have indicated that the profession will offer competitive professional services in the future by cultivating management orientated competencies. In their feedback, architects and consulting engineers suggest that the future competencies of quantity surveyors still lie in IT-driven technically orientated competencies. Both parties generally agree on the current proficiency levels of quantity surveyors in the defined competencies in this research. In terms of the aggregate ratings by both parties, quantity surveyors display above average proficiency levels in less than one third of the defined competencies, a less-than-satisfactory situation.

It can be concluded that the education of professional quantity surveyors, current training and retraining through continuing professional development should be strategically focused on improving the performance levels of quantity surveyors in the competencies generally recognised as critical for the future success of the profession. Additionally, the quantity surveying profession through concerted efforts of individual professionals, individual firms of quantity surveying practices and the Association of SA Quantity Surveyors should strive to improve the level of awareness of other built environment participants about the repositioning of quantity surveying competencies from technically orientated services to management orientated services. Successful provision of management orientated services in project or advanced financial management should be more widely publicised within the construction industry. The study has also shown that quantity surveyors could beneficially exploit the competencies of structural knowledge and expert witness, which at present fall in their 'blind' or hidden window of a Johari analysis.

Finally, the methodology adopted in this study can be used to audit the competencies of other built environment professionals for more effective communication among participants in the construction industry.

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Appendix: Competency headings and summary outcomes

Competency Heading	*Summary of Abilities/Outcomes*
Advanced financial management	Interpretation of financial statements, business positions, sources and uses of funds; application of accounting principles
Arbitration and dispute resolution skills	Understanding of and ability to advice on arbitration and other dispute resolution procedures including the relevant law
Computer literacy and information technology	Understanding and use of current information and communication systems, basic and specialist software and the Internet
Construction contract practice	Knowledge of, distinctions between, and advise on forms of contract
Construction technology and environmental services	Understanding of the organisations and practices in the construction process, execution of construction technology, principles of health and safety
Development appraisal	Understanding and execution of development appraisal; identification, assembly and use of relevant data
Economics of construction	Assessment and control of construction costs and risks
Expert witness	Demonstrating the ability to generate and present evidence, understand legal procedures and stay calm in tense situations in court
Facilities management (FM)	Understanding and application of the principles of FM including strategies, processes and systems
Law	Awareness and understanding of, and ability to apply relevant law
Leadership/general management skills	Understanding and ability to apply leadership, decision-making, teamwork
Macro-economic perspectives	Reflection of global economic data in economic and business analysis
Managing of joint quantity surveying appointment	Understanding the dynamics of joint appointments; negotiating and managing potential or actual conflicts for win-win collaborative outcomes
Mapping	Understanding of reference systems, scale, two-dimensional drawings

Marketing	Understanding of quality service delivery and marketing principles
Measurement	Understanding and accuracy of measurement of construction works
Personal and interpersonal skills	Communicating effectively; self management and people skills
Procurement and financial management	Documentation and administration of project procurement process
Professional practice	Recognition of the significance of property, ethics of professional practice, role of the professional associations, applicable legislation for practice
Project management	Managing the delivery of projects with appropriate tools and people skills
Property investment funding	Understanding the importance and alternative sources of real estate finance
Research methodologies and techniques	Demonstrating familiarity with, and sources of data, and manipulation techniques; application of analysis and interpretation to client requirements
Skills in managing a business unit	Recognition of client needs and cost-effective uses of appropriate resources; quality control and assurance
Skills to work with emerging contractors	Demonstrating an awareness of and ability to deal with special needs of small local contractors with limited managerial skills
Structural knowledge	Demonstrating an understanding of the principles of structural systems including loading of structures, bending, buckling and bracing, and cross-sectional properties of construction materials

A SURVEY OF CLIENTS' OF CONSTRUCTION IN THE CARIBBEAN REGION.

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ABSTRACT

Concern has been expressed in many quarters in the Caribbean Community about the competitiveness of the construction industry, particularly in relation to large-scale projects. In order to gain some insight into the situation a major study is being conducted, and it will be reporting in the near future. As part of this study a questionnaire based survey was conducted of the major client organisations in the region – both public and private sector. The results of the survey showed that the clients were generally dissatisfied with the performance of the industry.

Keywords: Caribbean region, survey, construction industry competitiveness.

INTRODUCTION

In recent times concerns have been expressed that the construction industry does not appear to have been very effective in winning bids on large projects within the Caribbean region. Neither the projects nor the firms that are considered large in the local context, would normally be considered large in international terms. The limited number and scale of the projects naturally limits the size that a firm can afford to grow to, and be in a position to sustain through a continuous workload. Thus, 'large' must be recognized as being a relative term. However, given these market limitations it becomes even more critical that the 'large' local firms win the 'large' local projects or their own future prospects will be handicapped and the local industry will find its sectoral share of the Gross Domestic Product shrinking further. For these very valid reasons, the larger local firms must feel that they are getting a fair shot at winning the larger local projects. The industry in the region has a great belief in its own technical ability to undertake the construction projects that arise within its home country, and within the region. For the most part, the major projects that do arise are of no great technical difficulty, involving, as they do, mainly road and pavement construction, pipe laying and building works.

There is, however, a very clear and strong perception within the industry that local firms are disfavoured and disadvantaged in internationally bid projects, especially those that are in any way funded by international agencies or organisations. This has been reported in formal studies undertaken by the Department of Civil Engineering at the University of the West Indies (e.g. Anthony & Lewis, 2000), and there is a vast array of less formal, media and anecdotal support. It is also apparent in the responses to a survey conducted recently (Lewis, 2002) that the majority of firms involved in construction work feel that they did not stand an equal chance of winning such projects. Some of the results of that survey are presented and discussed here.

The public perception is also that there has been some impropriety involved in the award of the contracts for these projects. This is fuelled by the sense of disbelief that foreign firms are so much better than local firms that they can consistently beat the local firms in free and fair bidding. This view has been reinforced by a fairly constant stream of articles in the press and widespread rumours about corruption and unethical goings on.

Issues relating to the concerns of the consultant and contractors locally are reported elsewhere, while the focus here is on the responses of the major clients of construction projects to a questionnaire directed towards their satisfaction with the services they receive.

THE SURVEY

A large number of questionnaires were sent by mail, hand delivered and emailed to various client organisations throughout the region from five main centers – Barbados, Guyana, Jamaica, the Organisation of Eastern Caribbean States (OECS) countries and Trinidad & Tobago. Poor record keeping in some of the countries and distribution through email means that it is impossible to know how many questionnaires were sent out and therefore what the response rate was. In the event just 16 organisations responded. The results of the survey are discussed in percentage terms, and where the percentages do not add up to 100%, this is because the respondents often missed out questions, simply made comments, or gave inappropriate answers (which were thrown out), or because they gave multiple answers when more than one answer was relevant. To try to be consistent percentages have been used throughout.

It should also be noted that no attempt has been made to separate out any regional variations in the responses given, for example, as between the clients in Trinidad & Tobago and Guyana. Given that many of the client organisations are regional in their operations (e.g. banks and insurance companies) there seems little to be gained, anyway, by trying to be country specific. For the purposes of this study and the formulation of regional policy, it is the overall summary position that is the relevant viewpoint. Thus, the data have simply been accumulated and converted into a common currency base where necessary.

As noted, a total of 16 client organisations responded to our survey. These were distributed, 1 from Jamaica, 1 from St Kitts & Nevis, 8 from St Lucia and 6 from Trinidad & Tobago. This sample covers both public and private sector organisations that 'often' procure construction services. In this regard, the public sector is of prime importance throughout the Caribbean region, as it is far and away the major purchaser of construction services. However, there was considerable resistance from many public sector organisations to filling out the questionnaire, usually on the basis that clearance was required from the Permanent Secretary or Minister before any such information could be provided – and the necessary clearance was never obtained. This is felt to be a sad hangover of colonial bureaucracy where opacity rather than transparency was the order of the day. None of the information requested here could be considered 'sensitive' or 'commercially valuable' and its availability could help improve the workings of the system. However, although the numbers may seem relatively small, they do include many of the more important clients in the region, including a reasonable number of public sector agencies.

The vast majority of these organisations have been in business for more than a decade, with 81% of the responding firms having been established before 1990 and 6% being established between 1990 and 1995. As one would expect, the major purchasers of construction services tend to be the more mature organisations.

PROCUREMENT STRATEGIES

All of the responding firms, naturally, operate in their home country, with 75% saying that they only operate there, 13% indicated that they also operate within the Caribbean region, and 6% operate internationally. Obviously, the public sector organisations only operate on a local basis, and their orientation does tend to distort their responses when compared with commercial organisations. For example, public sector organisations are often expected to compromise efficiency for social responsibility, which is fully understandable, but does mean that their responses will not necessarily address or advise issues of economic effectiveness.

This tendency to compromise efficiency shows up in their response to questions about procurement strategy, where they act in one way when given freedom of choice, but another way when their choice is constrained. Hence, when asked whether international tenders were invited for new structures, quite naturally, the public sector organisations said 'No' with the qualifying comment "Unless working with international lending agencies". As a result, 75% of the client organisations indicated that they only called for local tenders, 25% said that tenders from firms within Caribbean were invited and 25% said that international tenders were invited.

Many public and private sector organisations nowadays use different forms of procurement like Design-Finance-Construct (DFC), Build-Own-Operate-Transfer (BOOT) and Build-Own-Lease-Transfer (BOLT) to acquire facilities. In some cases, private sector organisations (like insurance companies) take the lead by proposing and then getting involved in the provision of public sector facilities by being part of the consortia that undertake the projects. In other cases, the public sector identifies socially desirable facilities – that it cannot afford out of its current budget – and allows the private sector to put together a package to provide the facilities, and to finance them out of revenues or out of future budget allocations. When the client organisations were asked if they used these approaches, 44% said 'Yes' while 50% said 'No'.

A follow on question asked whether the organisations undertake 'speculative building'. All public sector client organisations said 'No' – presumably because the demand is there before they procure the facilities they need, rather than building ahead of demand - which is what the term 'speculative' suggests. By the same taken, many of the private sector clients who build residential complexes try to pre-sell those facilities and hence establish demand ahead of procurement. However, all private sector building of this nature (i.e. apartment towers, or office blocks built by insurance companies, for example) whether effectively pre-sold or not should be considered 'speculative'. This was not clarified for the participants, and the confusion may have led to a lower response rate to this question, with 63% saying they did not undertake speculative building and only 19% saying they did.

Recognising that there are synergistic benefits to be obtained from successful and repeated teamwork, the client organisations were asked if they had an understanding with a client and/or a contractor for undertaking construction projects, either to provide facilities for other clients or for themselves. 63% said 'No' and 31% said yes. One organisation noted that it always used the same contractor, but dealt with different consultants depending on the nature of the project.

Most public sector agencies that undertake significant procurement of construction services want to have representation on the project management team, either through their own personnel or through some other agency or Ministry. In the same way, many private sector client organisations have strong management capabilities and want active representation on the project management team. It was not surprising, therefore, that 63% of respondents did get involved in the management of their own projects, while 31% did not.

Where a level of expertise in a specific discipline is identified as an organisational strength, it is common for industrial organisations to try to exploit this. Similarly, where a public sector organisation has a capacity, it is there for a specific reason, and will often be used in similar circumstances for other public sector organisations – hence a Ministry that has construction project management skills will usually be expected to apply those skills to the benefit of other Ministries. Thus, the client organisations were asked if they used their project management skills for other owners, and 44% said they did while 44% said not.

LEVEL OF SATISFACTION

The success of any industry can only ever be judged by the satisfaction of its customers. No matter how good a job one thinks one is doing, if the customer is not satisfied then the work has not been done well. The principal objective of this study was to investigate the competitiveness of the local industry, and so finding how satisfied the industry's customers were was a key issue. This section of the questionnaire addressed the (subjective) satisfaction of the client to the services provided by both local and foreign firms.

When asked whether they were satisfied with the performance of local consultants, 63% of clients said 'Yes', while 31% said 'No'. The fact that half as many were dissatisfied as were satisfied cannot be considered acceptable by local consultants, particularly in view of the fact that amongst those expressing satisfaction, several commented along the lines "In general, yes, however the performance of some has been wanting" and "Predominantly professional services are provided, however there is room for improvement". Some of the clients who were dissatisfied were quite strongly critical.

Local contractors fared even worse than the local consultants, in that 56% of clients were dissatisfied with their performance while only 31% were satisfied. Again, this question provoked quite a number of comments, many focusing on the lack of qualifications of local (small) contractors. The list of areas of dissatisfaction would cover the gamut of the managerial responsibilities of a contractor, and a majority noted that local contractors require a disproportionate amount of 'supervision.' There is clearly no room for complacency by local contractors in the Caribbean region. The majority of their clients are dissatisfied with their work.

To see whether foreign consultants and contractors fared any better, the same questions were asked about satisfaction with the services they have provided historically. 69% of the client firms that had used foreign consultants were satisfied with that service while only 6% were dissatisfied. While this relatively high level of satisfaction could be considered a resounding recommendation, a number of comments indicated that everything was not as 'rosy' as it first appeared. Firstly, it was noted that although foreign consultants are "generally more effective", they are also more expensive – this is not an insignificant issue given the complaints of local consultants that their own fee levels are too low. Secondly, there were a number of comments along the lines that foreign consultants "still appear to have the feeling that they are dealing with 3rd world countries and as such their work/attitudes reflect this" and "some firms come with a "my-way" attitude, despite the Terms of Reference". In other words the clients seem to feel that foreign consultants tend to be rather arrogant, and although they respect the consultants' expertise they resent their attitudes.

When asked if they were satisfied with the work of foreign contractors, only half of the sample had had experience and were able to respond. Of these exactly half were satisfied and half dissatisfied. Although they fared better than the local contractors, there are clearly problems for local client organisations with the service provided by foreign contractors. This gives the lie to the perception that everything will be okay if it is done by big foreign contracting firms, and substantiates the view of the local industry that you cannot guarantee competence just because it is imported and expensive. Comments explaining their responses indicated that the clients felt foreign contractors to be no better and no worse than local contractors.

COMPETITIVENESS

The Western economies depend on competitive markets to try to establish transaction efficiency. To be competitive a market needs a 'large number of willing and able' sellers so that the customer has effective choice. To see if clients felt they had adequate choice, they were asked if they felt the local market for consultants was competitive enough. 56% said that it was not, while 31% said it was. The comments indicated that the clients felt that there were not enough new firms entering the market and that the lack of competition was leading to a falling off of the standards of service.

A similar response was obtained when the same question was asked about local contractors. In this case, 63% said it was not competitive enough while 31% said it was. The comments indicated that the clients saw a cut-off point in the size of projects above which the local market ceased to be competitive. One indicated that the cut-off was around TT$50 Million (US$8.5 million); on larger projects there are only a few local firms competent, and as a result, overseas contractors would tend to be used.

CONTRACT PERFORMANCE

Contractors and Consultants were asked during this study how they felt about the bonds and financial preliminaries that arise before projects start and the liquidated damages that arise after the project's completion when it is delayed. Both of these items are supposed to give the client some measure of financial protection from poor performance by the contractor on his project. However, they both introduce an extra level of cost, for eventually the client has to pay for them. When asked if they though the cost of the financial preliminaries was justified 88% said that it was, while only 19% said not. Although this represents an overwhelming vote of confidence in the need for bonding and insurance etc., a number of comments did qualify the affirmation. In particular, the clients felt that the historic performance of the contractor should be taken into account in arranging the bonds. If a contractor performs consistently well, why should he face the same bonding requirement and the same charges at the banks or other bonding institutions as one who has a lesser record of success? Presumably if the charges came down for the good contractor, then so would his price to the client – a classical win-win situation.

The situation was less clear cut with the provisions for liquidated damages, but still quite solidly in favour, with 56% saying that their levels were logical and justified and 31% saying not. The comments also told the same tale, with several responding that they were "not sure", and several commenting along the lines "I am not sure they are tied to the loss suffered by the user for lack of use" while still affirming their value. There is perhaps a need for consultants and clients to look at the figures used in the provisions for liquidated damages and also to consider the option of paying a bonus for work completed ahead of schedule (though this would require careful attention to be paid to the development of the baseline schedule).

Given that the countries of the Caribbean have been susceptible to exchange rate changes and relatively high rates of inflation, the clients were asked the same question as the consultants and contractors about their attitude to a 'fluctuations' clause in their contract documents. Would the client rather pay a premium for the contractor to assume the price risk or would they prefer to forego that premium and assume the risk themselves? Interestingly, the majority (50% to 38%) said that they would prefer to take the price risk themselves, thus indicating that they were well aware that the contractor's premium would probably provide him with a substantial comfort margin. Those in favour did have some reservations, indicating that the fluctuations clause should be restricted to certain items or to certain specific, unexpected circumstances. For organisations that have to specify the budget for a project at the outset, this would not be appropriate, as they would find it difficult to fund increments due to an exchange rate change or sudden inflation. Again, it was noted that in Jamaica, for example, some contracts do include an 'escalation clause' that allows for various elements of the contract price to be increased under certain specific conditions. As they are currently written, however, these escalation clauses do not give the contractor much protection especially in a country like Jamaica that has suffered from a fairly severe recession over the past decade or so, and has seen the value of its currency decline dramatically.

PROJECT PERFORMANCE

To extend the issues being examined under the heading of client satisfaction into more objective territory, a number of questions were asked that related to actual project performance. Hence, the client organisations were asked if their projects were normally delivered on time, and while 31% said 'Yes', 63% said that they were not. When asked to indicate how serious the delays had been the firms indicated that a worst case scenario was around the 100% mark, and the average between 15 and 25%. Some speculated that the reasons for the delay varied between over-optimistic scheduling, poor design, scope changes and variations.

The three key parameters in project delivery are time, cost and quality, so having asked about the timeliness of project delivery, the focus was then put on cost and quality. Thus the client organisations were asked if their projects were normally delivered on cost. Given the poor time performance, it was reassuring that 56% said that their projects were normally on cost as opposed to 31% who said not. An average cost overrun of 20-30% was indicated by one client who had not had a good experience.

To complete this section the questionnaire asked if the projects were normally delivered at an 'acceptable quality level'. A very satisfactory 81% said 'Yes', while 13% said 'No'. These results suggest that the industry puts most focus on providing a satisfactory product for the client in terms of quality, the secondary objective is delivery on cost and timeliness is a somewhat distant third. This is probably a fair reflection of the culture in most of the countries of the Caribbean region!

PROJECT SIZE AND MARKETS

The next section of the questionnaire addressed the client organisation's normal scale of operations. Because we are dealing here with organisations that tend to be repeat clients and that their projects tend to be larger than average, it is not surprising that their average project size was also large. Hence, 69% indicated that their average project size was over US$ 1 million. 19% indicated their average project to lie in the range US$100,000 – 500,000, and 6% indicated an average project size less that US$100,000.

In a similar way when asked what was the largest project that the organisation had ever been involved in the majority (56%) indicated over US$20 million. This is quite a large project by local standards. 6% indicated their largest project to have been in the US$ 10 to 20 million range, 25% indicated between US$ 1 and 10 million, and 13% indicated that their largest project was between US$500,000 and 1 million. None selected the option for a project size smaller than this.

These client organisations, being repeat purchasers of construction services may also be expected to have more than one project under way at any time. It was rather surprising to learn, however, that 38% of them had had more than 10 projects going at a time. A similar 38% had been involved in between 1 and 5 projects, 19% had been involved in between 5 and 10 projects and only 6% had ever been involved in only one project at a time. Given the average project size indicated above, this does seem to suggest that there is a valuable market for construction services on larger projects.

Because this study is concerned with issues relating to the competitiveness of the industry in regional and international terms, it was of interest to find out how many client organisations were involved in project development in more than their home countries. Although 69% of the organisations indicated that their only market was in their local home country, 19% indicated a market involvement with other CARICOM (Caribbean Community – mainly English speaking, ex-colonial) countries, and 6% with other Caribbean countries. It is interesting and reassuring to note that clients are also looking at the region for developmental opportunities not just their home country. Obviously, the public sector organisations in each territory are only looking inwards, so the private sector representatives are even more active than suggested by the figures here.

The situation is even more reassuring when looking at the figures representing the organisations' plans for the next year or so. While 63% of the organisations said they would only be involved in projects within their own home country , 13% said they would get involved in projects in CARICOM, 13% said the rest of the Caribbean, and 6% would get involved in projects internationally.

ADDITIONAL COMMENTS

When asked about their knowledge of the move by CARICOM to establish a Single Market and Economy (SME), it was again clear that there is a need for an educational effort. 56% of client organisations indicated that they were unaware of the protocols being negotiated on their behalf by the Caribbean Regional Negotiating Machinery (CRNM – the agency charged with the responsibility for negotiating the terms of trade between the SME and other international trading blocs like the FTAA), while 19% said they were aware. 31% thought the protocols affected them while the same number (31%) felt that they did not, and, 75% wanted to know more about the protocols and what is going on, while only 6% were not interested.

Only one final comment was appended to any of the questionnaires, but it was a very relevant comment, so it is given here in full, *"There seems to be an imbalance in the number of projects awarded to international firms against local and regional. While it can be argued that the regional firms are not outfitted (financial, expertise, equipment, man power) to undertake major regional projects, the international firms should be somehow forced to joint venture with local regional firms on projects where this is the case. The results of such could prove to be extremely beneficial to the regions quest for development of expertise on the construction arena and could continue to bring financial benefit to our regional companies, not to mention education and development of the industry"*. This makes interesting reading coming, as it does, from a client.

ACKNOWLEDGEMENT

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Management of qualitative transition changes in construction sector

Prof. Mladen Radujkovic Ph.D.

ABSTRACT

Transition is a global change of political, economic and social components of a society carried in more than 20 ex socialist countries. The paper briefly describes the present state of the transition process in some of those countries and it's influence on construction industry. Enclosed comparison of previous and actual statistical data for construction sector confirms trend of significant and rapid structural changes. However, despite of undoubted quantitative aspect of accomplished changes more detailed analyses of the present state show that present stage is far from having half of the job done. The present business practice implicate operating under heavy pressure of many transition changes, in bits risky environment, with a shortage of money on the market, without necessary management skills, dealing with totaly new business concepts,... , so many systems are currently carrying it just as an battle for survival. Such orientation produce negative climate for introducing a long term business strategy and necessary qualitative changes within construction sector. Only balance between quantity and quality of changed can garantee perspective future for domestic construction industry in inferior transition countries that have accepted globalisation and opened national market. The process of adopting necessary knowledge, experience, international criteria and practice, world valid standards, and other supporting items should be done in a thorough way through market changes, but also by parallel changes within companies and in individuals working in the construction business. However, the only successful way is leading to new projects and aplication of working+learning+changing+controlling concept during the transition period which characterize efforts in adopting international criteria and standards for measuring success.

The paper deals with the balance between present state, needs and capabilities of construction sector in transition economy. Necessary future qualitative changes within construction sector are described in the context of international standards and criteria. The roles and responsibilities of all stakeholders are commented including the presence of the better – bigger – faster syndrome and it is influencing the performance and competitiveness in both positive and negative ways. Significance of professional management at all levels of business, and particulary at project level, is particularly analyzed as a key point for introduction

and implementation of necessary qualitative changes. Description include some issues that are presently designed and realized close to a satisfying level, but also some, such as competitiveness, sustainability, maintainability, flexibility, innovation, aplication of IT, as well as production cost and time, that are still far from final target value and therefore currently adversely influence construction business in transition economies. Based on results of research of that area in the final part of the paper some recomendations for improving process within construction sector in transition economies is proposed. In that way all stakeholders are strongly invited to support the process of qualitative changes to satisfy the expectations of the transition society, so business entities and individuals within construction sector, for development and progress.

CHANGE PROCESS IN COUNTRIES IN TRANSITION

Transition is a process in which over 20 ex-socialist states are changing their political and economic attributes. The process is characterized by its wide scope of influence, simultaneity and speed. It can, therefore, be said that there are few historical examples where such a deep and complex change is occurring through an entire society. The beginning of transition is considered to have been in 1990, when unstoppable political change occurred as a wave (Table 1.).

Table 1. Comparison of pretransition and transition periods

num.	Characteristic	Pretransition period	Transition period
1.	Political system	One political party	Multiple political parties
2.	Social system	Socialism	Capitalism
3.	Political association	Warsaw pact (some countries)	NATO (some countries)
4.	Country territory	Multiethnic states (federations, etc.)	National states (new countries are formed)
5.	Territorial boundaries	Political accords after World War II	Bilateral accords (partly), war among countries (partly)
6.	Political laws	rights of the majority	Individual rights
7.	Political of private ownership	Socialization	Privatization
8.	Economic system	Planned economy	Market economy
9.	Economic		CEFTA, EC (some

	association		countries)
10.	Ownership	Mostly state, social	Mostly private
11.	Interstate exchange	Clearing (goods for goods)	Monetary transactions
12.	Price regulation	Central (most countries)	Market
13.	National market	Closed	Open for competition from other countries
14.	National currency	Only for domestic market	Convertible, EURO
15.	Foreign investment	Limited cases	Attraction emphasized
16.	Banking system	Under political influence	Market laws
17.	Work force	Closed market	Possible fluctuation and employment of foreigners
18.	Losses in business	Covered by social net	Owner's expense
19.	Standards and norms of production	Concentration on technical quality of products	All international criteria (quality, cost, time,...)

Although all the countries are going through similar changes, their transformations are significantly varied. The sources of this variation must be looked for in the differing starting positions of 1990, occurrence of regional wars among certain countries, influence of varied geographical positions, differences in cultural heritage and traditions of individual nations, and the political will of individual nations for direction and dynamics of change expressed through elections. The different positions in 1990, were the result of different types of socialism (Russian, Chinese, ex-Yugoslav,...) of which the ex-Yugoslav was probably the most economically liberal in that it allowed private ownership for entrepreneurs and small businesses, fluctuations in the workforce, possession and payment in foreign currencies, free formation of prices for all products other than those that are elementary for everyday life of individuals, ... Unfortunately, it was part of ex-Yugoslavia that experienced war, and this eliminated the its beginning "advantage" and significantly slowed down the process of change (except the Republic of Slovenia). The political will of individual nations influenced the speed of the transitional changes, so the Czechs, Poles and Hungarians elected parties that led them to fast changes, while the Romanians and Bulgarians chose somewhat slower changes (Crina Olten-Dumbrava 1996.). Statistical indicators are important since they show various oscillations in individual countries (Figure 1.).

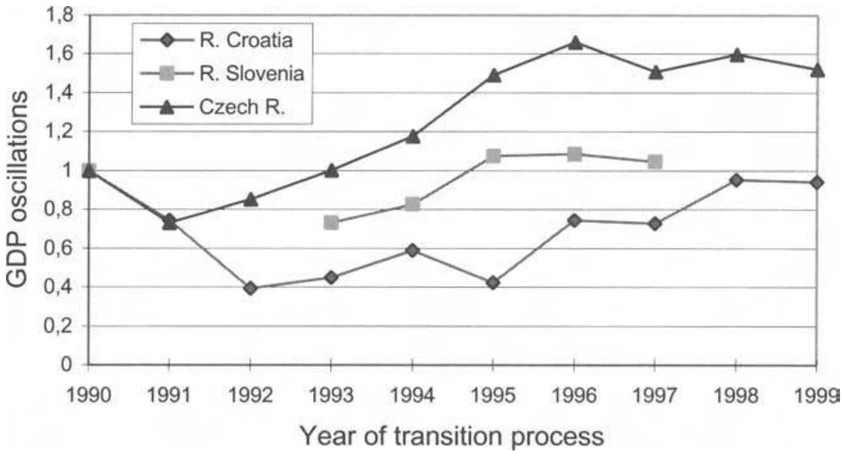

Figure 1. Oscillations of BDP in three transitional countries with various political paths (1990, this year is the base year with a value of 1.) (Radujkovic, 2001.).

CONSTRUCTION IN COUNTRIES IN TRANSITION

In most ex-socialist countries construction was an important business branch because through massive and fast construction there was a need to show advancement of society. Therefore, construction had a significant stake in the BDP (7-10%), very good consistent workforce with significant numbers of employees. The organizational strength of construction represented up to 50 large national companies, alongside of which there usually existed at least one local or regional construction company.

Construction is a branch that is not on the "attractive list" of investment of capital because there is not a large margin of profit and every political or economic change in society has a significant influence on it. In countries in transition people in construction were among the first to feel the influence of transitional change (Figure 2.). The need for fast adapting inside the business sector and each company was satisfied mainly by adapting to new laws and regulations, and through several quantitative measures (Table 2.).

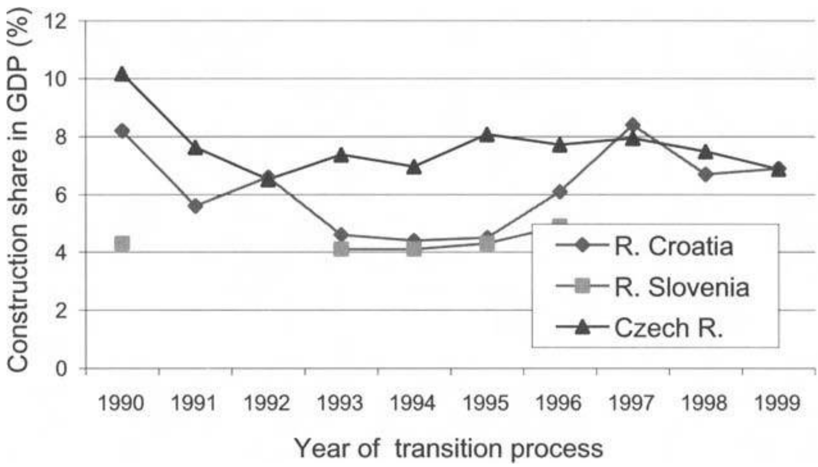

Figure 2. Oscillations in the stake of construction in the BDP in three transition countries with different political paths of transition (Radujkovic, 2001).

Table 2. Overview of main changes in construction company.

Num.	Characteristic	Pretransition period	Transition period
1.	Main investor	Government	Public and private
2.	Primary construction	Massive apartment, industrial complexes	Infrastructure, maintenance
3.	Ownership of companies	Government, public	Private, shareholders
4.	Organizational structure of companies	Functional	Functional, project, or matrix
5.	Structure of companies	Domination of large companies	Domination of small companies
6.	Number of employed in company	Large	Small
7.	Structure of employed in the company	Large number of administrative workers	More productive workers than administrative
8.	Scope of company	Wide	Tendency toward

	business		specialization
9.	Competitiveness of company on the market	Low	Medium
10.	Business orientation	Employee satisfaction	Profit, investor satisfaction
11.	Success criteria of project	Technical	Technical, financial, schedule
12.	Standards of quality of products	Domestic	Tendency toward international
13.	Machine equipment	Wide range	Specialized, renewed
14.	Management	Various committees, influence of politics, bureaucracy	Owners, Board of Directors

Analysis of the changes to date in the construction sector show that the following have been successfully performed:

- Shift in the ownership structure - privatization.
- Registration according to new laws and regulations – shareholder groups.
- Division of large companies into large numbers of smaller cells.
- Registration of a large number of new small businesses.
- Separation of nonconstruction and secondary services in companies – service portfolio cleaning.
- Significant reduction of number of employees, especially in administration.
- Specialization of parts of companies.
- Aggressive approach on the market with the aim of winning bids.
- Finding a strategic partner with the aim of improving the financial condition of the company.

Measures taken until now can be characterized as mainly quantitative adjustment. In this way, for example, in the Republic of Croatia the number of companies registered for construction has increased 12 fold, while at the same time the number of employees has decreased by around one third. The aim of the adjustment to transitional changes in the first phase can be summarized as winning (or losing in some cases) the fight for survival of the company. For those who continue functioning, the next aim is to improve the success of their business, or to continue improving success which can be achieved only through qualitative changes.

QUALITATIVE TRANSITIONAL CHANGES

In the turbulence of all large changes every business system, regardless of its real abilities and quality, sees a chance for positive change. Even though business systems mainly adapt to certain external requirements, the wheel of change usually starts up internal forces that desire qualitative changes in the system. Without a well prepared program, most fast changes in the system follow the "better-bigger-faster" motto, which usually means wasting large amounts of energy and resources with an unpredictable success rate in the end. The introduction of qualitative changes is actually a project that needs to have a plan with clearly defined significant characteristics in relation to contents, participants, goals, duration, structure, phases, limitations, roles and responsibilities, methods,... One of the largest problems in most transitional construction projects is the lack of good plans for qualitative changes. In designing a plan the following should be performed:

1. Data collection within the business system and around it.

2. Development of a concept for managing changes.

3. Formation of a team, determination of roles and responsibilities.

4. Make a program and plan for changes, approve the program and plan.

5. Carry out the program and plan.

6. Monitor and control carry-out.

Some of the most important questions that determine the quality of change, and that need to be clearly addressed in the program are:

- Stronger project orientation in the organization of the business system. Complete adapting to market criteria for valorizing business success for individuals, teams, companies,... General increase in productivity and competitiveness in the construction sector.

- Raising the level of knowledge and ability in project management, including stronger investment in knowledge of employees in positions of responsibility. Creation of a pyramid of managers for successful management on all levels of the business system.

- Strengthening of computer support for business, and application of advantages of computer use with integrated planing processes, monitoring and control at the business system level.

- Improving understanding of main goals, scope, success criteria and life cycle of the project by all participants in the project. Developing partnership relations between key participants in the project based on "useful for all partners through development of useful flow and maintainable project characteristics".

- Stronger integration of individual participants or work with the goal of reducing the number of changes in the projects during the carry-out phase (i.e. design-construct / buildability approach).

- Creation of a special strategy for reduction of overruns of planned project time and cost (Figure 3.).

- More proactive approach towards application of innovation in technology, organization and management in the construction processes. Incorporation of new proven solutions and investment in "in-house" innovation and business.

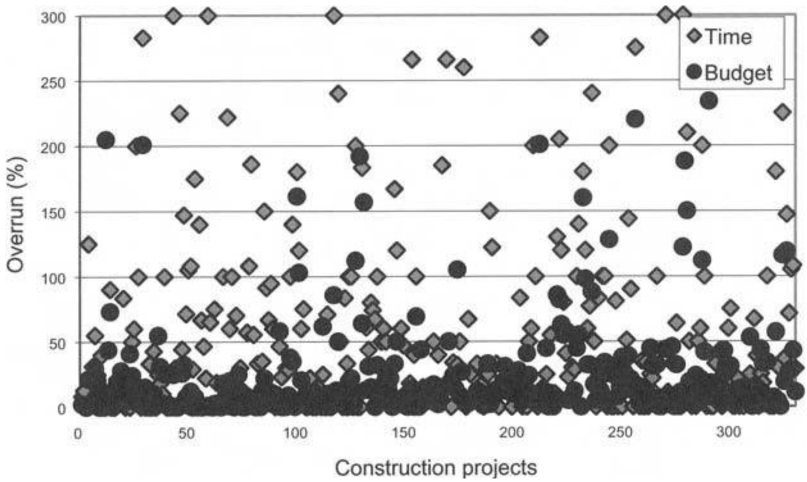

Figure 3. Data on time and budget overruns for construction projects Croatia y. 1995-2000.

The proposed measures for qualitative changes in the construction sector in transition countries represent a logical series of steps after already carried out quantitative changes. It is to be assumed that qualitative changes will be more difficult to perform, because they require simultaneous adjustment within the construction sector, the company, but also within each individual. Due to the high amount of manpower required in production and low hourly wages of workers, construction in transition countries will not be affected greatly by foreign competition from developed countries. However, should qualitative changes and adapting to changes be overlooked in the most attractive domestic projects and companies, investors and owners will install experts, directors or branches of foreign companies, and domestic resources will be used as sub-contractors or co-operatives. Therefore, it needs to be recognized that the ability to manage is equally valuable as the ability to build, but also that domestic management abilities in transitional countries today are significantly lagging behind in relation to developed countries. Without fundamental changes in relation to management of business systems transitional construction will not be compatible with businesses of investors, end users and financing of construction services, which is today the most obvious danger for further development of this branch. In this case the list of ongoing problems remains as is shown in Figure 4.

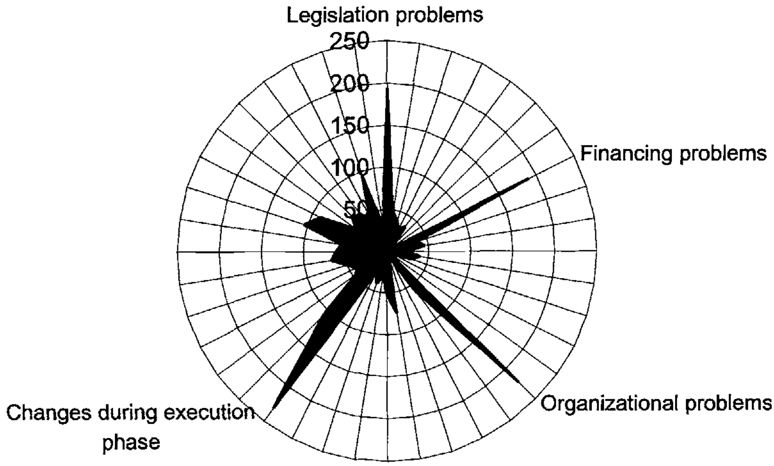

Figure 4. Results of research into four main sources of problems that cause deviation from original planned goals in business.

CONCLUSION

In the construction sector of transition countries quantitative measures of adjustment have been performed through legal and economic changes in society. Through the next period there have to occur qualitative changes in order to achieve the ability of performing business compatible with the business needs of investors, users and financing of construction services who apply international standards and criteria.

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Competition and Barriers to Entry the Construction Sector

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ABSTRACT

In 1999 Sweden and Denmark were physically linked for the first time by a bridge bringing the countries even closer. The bridge connects the capital area of Denmark and the south part of Sweden in an area called the Öresund region. At a national level there is a mutual political interest to create an integrated market in the Öresund region and in a wider perspective the bridge is a physical contribution to the common market within the European Union. The objectives of this study are to describe the characteristics of competition in Sweden and Denmark as a means to identify barriers for companies in one country to entry the construction market in the other country. The paper is principally based on two separate meso-economic analyses of the Swedish and Danish construction sectors presenting some basic characteristics in figures and facts.

METHOD

A meso-economic analysis is the fundamental method chosen for this study. Meso-economics is the intermediate level between the microeconomic model (Greek micros – small) and the level of macro-economy (Greek macros – large) (Holland 1987). Meso-economics deals with entire sector economies and puts focus on industry structure in developed economies as well as the political dimensions of economic development and policy formation (PRESTON 1984).

Meso-economics constitutes an approach to a system, i.e. a way to look at and describe the properties of a system. When the meso-economic approach is applied on construction, the construction sector and all of its actors constitute the system. Accordingly, the meso-economic analysis is about analysing and describing direct and indirect actors of the system and its internal and external relations. In the meso-economic approach the principal purpose of construction is not only the production of buildings or constructions. Instead, it includes in a wider sense the production as well as management of the environment of a population. This puts focus on the services that buildings and constructions provide to end users rather than describing construction in terms of a production process. Further, the actors of construction include not only profit organisations but also non-profit organisations such as local and central government.

THE CONSTRUCTION SECTORS OF SWEDEN AND DENMARK

Sweden and Denmark are two neighbouring countries in the northern part of Europe. Sweden and Denmark have geographical areas of 411 000 43 100 square kilometres respectively which makes Sweden almost ten times as large. But, the Swedish population of 8.9 million is only about 70 percent larger than the Danish population of 5.2 million. A comparison on a national level shows that the size of Danish GDP is about 70 percent of the Swedish GDP. Both countries have a construction added value in GDP at a level of about 4 percent (see table 1.1).

Table 1.1 Construction added value in GDP (1995 Reference prices, Billion EUR) (STATISTICS SWEDEN, STATISTICS DENMARK)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Sweden	GDP	180.2	178.2	175.1	171.9	179.0	185.6	187.6	191.5	198.3	206.5
	Construction Added Value	9.0	8.9	8.4	7.5	7.5	7.6	7.5	7.2	7.3	7.7
	Added Value/GDP (%)	5.0	5.0	4.8	4.4	4.2	4.1	4.0	3.8	3.7	3.7
	Construction Investments	18.2	17.5	15.8	12.7	11.7	11.6	11.8	10.9	11.2	11.6
Denmark	GDP	123.1	124.5	125.3	125.3	132.1	135.8	139.2	143.3	147.2	150.4
	Construction Added Value	5.8	5.5	5.5	4.9	5.3	5.5	5.8	5.6	5.8	5.6
	Added Value/GDP (%)	4.7	4.4	4.4	3.9	4.0	4.1	4.2	3.9	3.9	3.7
	Construction Investments	12.3	11.0	11.0	10.9	11.0	11.9	13.1	13.8	14.5	14.1

The impact of the Swedish and Danish construction sectors on the national economy has decreased in the 1990s. For both countries GDP reached its lowest value in 1993 but then showed a stabile upward trend with an average annual growth rate of about three percent for the rest of the decade.

Between 1993 and 1999 the Swedish construction value of investments decreased by 9 percent. The reduced level of investments is most significant for residential building that dropped by almost 40 percent from 1993 to 1999 in Sweden while the share of non-residential investments increased by 30 percent.

Table 1.2 Investments by type (Billion EUR 1995 reference prices) (STATISTICS SWEDEN, STATISTICS DENMARK)

		1993	1994	1995	1996	1997	1998	1999	
Sweden	Total Construction	12.7	11.7	11.6	11.8	10.9	11.2	11.6	100.0%
	Residential	5.7	3.8	2.9	3.1	2.8	2.8	3.5	30.1%
	Non-residential	3.8	4.4	4.8	5.1	4.7	4.9	5.0	42.7%
	Civil-engineering	3.2	3.5	3.9	3.6	3.4	3.5	3.2	27.2%
Denmark	Total Construction	10.9	11.0	11.9	13.1	13.8	14.5	14.1	100.0%
	Residential	4.5	4.9	5.3	5.6	6.0	6.3	6.4	45.8%
	Non-residential	3.0	2.9	3.4	3.9	4.3	4.7	4.8	34.2%
	Civil-engineering	3.4	3.2	3.2	3.6	3.4	3.4	2.8	20.0%

The total volume of construction investments continuously increased in Denmark from 1993 to 1998, but dropped back in 1999. In the Swedish case investments decreased from 1990, reaching its lowest value in 1997. The level of investments in 1997 was only 60 percent of the total investments in 1990. The part of residential building showed the most significant changes in Sweden. The share of residential building dropped from 45 percent of total investments in 1993 to 25 percent in 1995. This low level remained unchanged until 1999 when a slight recovery could be identified. Construction investments in Denmark continuously increased from 1993 to 1999 and showed a more stable distribution between residential, non-residential and civil engineering investments. The share of residential and non-residential investments increased slightly at the expense of civil engineering investments that dropped from 31 percent in 1993 to 20 percent in 1999.

The trade cycles at the national level and for the construction sectors do not show significant deviations between the two countries. Both Sweden and Denmark are small countries that are influenced by fluctuations in the global economy. Consequently, differences in business cycles do not work as a promoter for integration of the construction sectors. If that would not have been the case, times of recession and the increased competition that follows, could be a driving force for construction companies to look for work in the other country.

COMPETITION IN A SUPPLY AND DEMAND PERSPECTIVE

The characteristics of construction influence the competition on the construction market. To describe the mechanisms of competition in the building sector of Sweden and Denmark a description of some significant aspects of the industry is put forward in a supply and demand perspective.

Supply Perspective

Construction is a local market in Sweden as well as Denmark. Any construction company that wants to compete outside its own local market are charged with transportation costs for labour, materials and equipment. This means that a company established on one local market has difficulties to compete for jobs on another local market. Primarily, this is the case for small and medium sized enterprises, SME's. The situation is somehow different for large companies. In general, the entry of a small as well as large company into the building industry or a new part of the industry is described as the process where the company decides to compete with the established actors in the market. The new actor on the market can be a newly founded company or a company that has previously been operating on another market. The difficulties in alignment with the entry of a new market are described as barriers to entry. De Valance (1999) identified a number of barriers to entry to the building industry:

- Cost of investment necessary to become a participant
- Market power of established actors
- Acquisition of the skills and workforce needed
- The state of the market

Valance (1999) describes the capital requirements to entry into the building industry as being low. Few items of plant and equipment have to be owned by the company. The market power of existing actors on the market are also described as low in case of the building industry, instead the need for a track record when tendering for large projects is pointed out as a determining factor. This is due to the risk associated with large projects and the fact that the contractor needs to demonstrate the ability to manage and co-ordinate large scale works. As there are only a few major contractors in Sweden capable of undertaking large projects, the need for developing good relations to important clients becomes a determining factor. These established relations constitute a significant barrier for new contractors to entry to the market of large projects.

Table 1.3 shows the distribution of Swedish and Danish contractors by size of work places. A work place is a self contained unit within a company, accordingly, each company has at least one working place. The contractor segment is very fragmented, divided into a large number of small firms. This is particularly the case for Sweden that is characterised by a vast number of small firms, few medium sized companies and three major construction companies which operates on the national as well as international market. Skanska, the largest Swedish contractor, is the fourth largest construction company in Europe. Denmark has a larger share of medium sized companies, which is due to a tradition of more divided contracts being used. The large Swedish contractors have a very dominating position on the Swedish market and further, they have taken over Danish contractors as a way enter the Danish construction market.

Table 1.3 Numbers of Contractors (Statistics Sweden, Statistics Denmark)

	Sweden		Denmark	
Size of work places (By number of employees)	Number of work places	Number of Employees	Number of work places	Number of Employees
1	13 112	13 112	2 810	2 810
2-4	6 855	13 053	1 838	5 112
5-9	1 709	11 204	1 200	7 972
10-19	1 170	15 834	733	9 778
20-49	711	20 917	481	14 628
50-99	207	13 951	140	9 567
100+	129	36 771	72	16 504
Total	23 893	124 842	7 274	66 371

According to the barriers to entry into the building industry described there appear to be two levels in operation. First, there are few significant barriers for small firms to enter the building industry. Still, when a small company established on one local market wants to compete outside its own local market transportation costs for labour, materials and equipment will be an impediment. Secondly, for large companies there are barriers to entry the market based on the need for a track record, financial capacity and technical capability. The need for established business relations is one explanation why large Swedish contractors have chosen to overtake large Danish construction companies as a way to enter the Danish construction market.

Table 1.4 shows the distribution of specialised contractors. Note that Danish specialised contractors have a greater number of employees, which describes a structural difference to Sweden. Denmark is more craftsmen oriented with a large number of small firms doing specialised works.

Table 1.4 Number of Specialised Contractors (STATISTICS SWEDEN, STATISTICS DENMARK)

	Sweden		Denmark	
Size of work places (By number of employees)	Number of work places	Number of Employees	Number of work places	Number of Employees
1	18 475	18 475	7 052	7 052
2-4	8 628	17 040	5 018	13 993
5-9	2 438	15 867	3 334	21 931
10-19	1 427	18 935	1 977	26 135
20-49	712	20 373	841	24 144
50-99	134	8 587	146	9 800
100+	47	6 636	48	9 795
Total	31 861	105 913	18 416	112 850

Demand Perspective

Clients are characterised by two main categories, the frequent professional clients and on the other hand low frequency or one-time clients. The professional clients repeatedly do business with major companies and consequently they establish a mutual relation and confidence in each other. This edified knowledge of each other's performance, business ethics, routines etc. promotes successful businesses. When a business relation is interrupted the buyer as well as the seller must invest in knowledge about new potential business partners. Thus, it is often profitable to maintain established business relations instead of continuously spending resources on comparing and evaluating various companies and their products, prices and qualities. (WIGREN, 2000).

Table 1.5 shows the distribution of real estate firms, property management firms and real estate agents.

Table 1.5 Numbers of Real Estate Firms, Property Management Firms, and Estate Agents (STATISTICS SWEDEN, STATISTICS DENMARK)

	Sweden		Denmark	
Size of work places (By number of employees)	Number of work places	Number of Employees	Number of work places	Number of Employees
1	34 718	34 718	8 661	8 661
2-4	8 558	13 873	4 150	10 754
5-9	1 117	7 119	1 148	7 362
10-19	613	8 148	431	5 675
20-49	394	11 490	167	4 907

50-99	111	7 288	41	-
100+	61	11 006	8	-
Total	45 572	93 642	14 606	42 105

One-time clients, i.e. mostly households, principally buy smaller reconstruction and maintenance services from the large number of small companies. Every household make occasional purchases, not co-ordinated with other households, and consequently they have a limited market position. One-time buyers do not share the advantages company relations and thorough knowledge about prices and quality like professional clients. Establishing business relations require time and resources and therefore compel to repeated business activities to be relevant. Consequently, one-time buyers of small jobs, e.g. maintenance, do not have economical incentives to make thorough market analyses. Instead, their choice of contractor could go to the most well known companies or be based on casual recommendations from neighbour or other friends. A buying pattern like this restricts the competition despite the fact that there are many buyers and sellers on the market. (WIGREN, 2000)

SINGLE MARKET AND MARKET FOR BUILDING MATERIALS

The climates in both Denmark and in the South of Sweden are the same and therefore same type of building materials can be used. The standards might vary between the countries for the housing, but is also a source of possibilities and innovative thinking. Better and cheaper solutions for construction should be applicable for both countries.

Through creation of the single market, different types of barriers between the countries within the EU would be removed. To make this come through it is necessary that the member states agree upon removing technical barriers and accept that products will be certified with harmonised standards and approved for use within the EU. The hope is to give the companies incentives to produce in bigger volumes, and be more efficient. More trades between the countries will increase the specialising within the countries and result in comparative advantages. A higher competitive level and growth will stimulate innovative process within the companies. The increased competitiveness is assumed to be useful for the clients through a higher supply and lower prices. (SOU 2000:44., 2000)

The Construction Products Directive, CPD will bring about free movement for construction products. A construction product is to be considered as acceptable if it can fulfil six different demands. The demands are for permanence, fire protection, health and environment, safety, noise protection, and heat and energy insulation. The six demands are made clearer in the application documents that are translated into all EU languages. The CPD covers all products that will be used permanent in construction or civil engineering projects. When a manufacturer have a product that fulfil the demands under the CPD, then it will get the CE marking that shows it has been certified.

Effects of economical integration

The economical integration has effects not just for the single country, but also for the other countries within the EU and the rest of the world as described in table 1.6 below. The two first cases describe the pattern of trade with changed trade barriers in opposition to miscellaneous EU countries. A decrease in the trade barriers can result in increased import from some of the member states at the expense of the domestic production. An increase of the trade barriers towards the Row's risks to increase the consumption of products manufactured inside the EU, at the cost of the import from countries outside the EU. The three last cases show the effects in the pattern of trades from trade barriers towards countries outside the EU. For a country with initially high trade barriers the new trade politics can reduce their hinder towards the ROW. This can lead to a situation where part of the import has been exchanged with less effective import from the EU. It can thus result in that an effective production outside the EU will be replaced with a less effective production within the EU.

+ = Increase of consumption share/ market share

- = Decrease of consumption share/ market share

Blank = unchanged situation

Table 1.6 Effects of economical integration (EUROPEAN COMMISSION, 1997)

Case	Description	Domestic	EU	ROW
1	Trade production	-	+	
2	Trade redistribution		+	-
3	External trade production	-		+
4	External trade redistribution		-	+
5	Trade reduction	+		-

The effect for the Swedish and Danish construction market with an economical integration within the EU will be that the market share for the local manufactures will decrease in favour of other manufactures inside the EU. For instance, with standards in common a barrier for economical integration will be removed and competencies and resources within the union will be used more effectively. The local companies then have to compete on the home market, but also get possibilities to enter other markets.

A NEW ERA FOR THE BUILDING PROCESS?

There are various interpretations of procurement systems between different countries. This creates a barrier for entry. The creation of new forms of procurement systems that are constructed in the same way in the different countries helps to remove this barrier. There are other aspects that constitute barriers such as standards, quality, etc. One definition of quality is to satisfy the expectations from the customer. The demands from the clients change continuously and in order to keep a position with high quality you need to improve constantly. There will always be new solutions that are innovative. Some changes are bigger than other and might even be consider as a paradigm shift for the construction sector. Two examples that describe bigger changes to the procurement system and building process follow. One is from Denmark and the other one in south of Sweden.

A Danish example of new types of procurement systems

In 1998 a programme was developed by the Danish Ministry of Housing and Urban affairs for better forms of co-operation. It included a total of eight projects. The objectives have been financial savings (5-20%) and bigger gross margins for the companies, better quality, fewer disputes, fewer defects on delivery, less wastage, fewer occupational injuries, active user participation and a better climate of co-operation. (STEEN OLSEN 2001)

The results of the first project are as follows. It was called “Martins Gård” and was handed over in 1999. The choice of contractor was not based at all on the price. Instead other aspects for selection were used. 25% was to be assigned to the professional capacity and 45% for professional experience, and 30% for personal resources. The chosen contractor could then in cooperation with the client and his consultants design the project. This gave possibilities for new technical solutions and to a different view towards financial aspects. The parties then work together with open cards and not as antagonists. When talking about open cards it is meant that profit are discussed and there will not be any secrets between the parties. Obviously this stimulates innovative solutions and more holistic thinking.

The outcomes of the new model are (STEEN OLSEN 2001):

- Agreements on open, constructive dialogue on all aspects of the project, including the financial aspects.
- Early selection of the main contractor and main participation by the main contractor in the design of the project.
- Active participation by the tenants in the phases of the building project.

- Even with a very tight budget, the client gets a project with the desired quality – which they would probably not get with the traditional procurement systems.

A Swedish example of new types of procurement systems

In the so-called Svedala concept new ways of thinking in the building process were developed for the erection of new apartment housing. The project was completed in two phases. The first one in 1992 and the second one in 1996. The inquiry for the project was formulated that all participants shall play with open cards during the process and a set level for the monthly rent as a goal to attain which is very low to be on within the Swedish market. The project demanded that all the actors strive together towards the common goal in the inquiry. The planning stage was the base for the project created. During the planning stage the customers were placed in the centre, alternative solutions were analysed and the purpose was discussed. (PERSSON, 2000)

The final result showed that the main goal with a specified low production cost and low monthly cost were achieved. This could be attained through new forms of co-operation were all the actors worked together and with innovative solutions. (SOU 2000:44, 2000) The procurement form that was chosen was the design-and-construct with functionality warranty. From the outcome of the project there has been an evaluation. One of them that are made by Nilsson (1999) includes a checklist for the different stages of the building process. These are to be used in future construction projects so the Svedala concept can be further developed.

Recommendations for the future procurement systems in Sweden and Denmark in general:

- It is important that the roles and authorities are clearly defined in all phases of the project.
- Involve the subcontractors rom the first stages.
- Use a wider decision base with more parameters than just the lowest price to choose contractor and subcontractors.
- Leave the traditional attitudes that are just to be concerned about the own financial interests. Instead think of what is best for the project.
- Use of other incentives than just financial ones.
- Decide early how to resolve conflicts.

Comparisons between new and traditional forms of procurement

In figure 1.1 an evaluation has been made as a further development of the model presented by Steen Olsen (2001) to compare some aspects of traditional building projects (black) and new forms of procurement (white). A few different aspects have been selected to give picture of the differences and similarities. The procurement systems are connected to barriers to entry Denmark respectively Sweden. The use of and the interpretations of the different procurement systems is a barrier between the two neighbour countries. Goals in common between the actors

- Individual goals achieved
- Use of innovative solutions in the process
- Use of benchmarking
- "Open cards"
- Contractors in the design phase
- Solutions through dialogue/ discussion between contractors from different areas.
- Life cycle analysis/ Holistic view

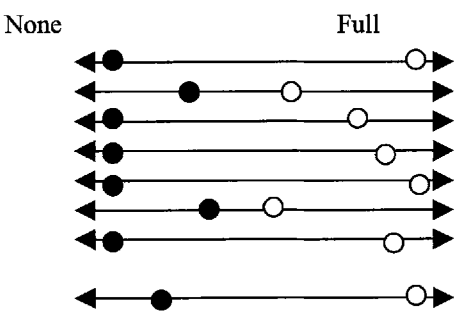

Figure 1.1 Evaluation of the traditional and new forms for building projects

- Goals in common between the actors: The goals are clearly defined in the inquiry and early discussions of joint objectives for the project are important for the team building. With goals in common and understanding among the actors there will not be any use in trying to find loopholes in the specifications etc.

- Individual goals achieved: With understanding of the parties different objectives it will lead to a higher amount of achieved goals when there is a greater understanding for each others problems. The individual actors will then set their goals based on what they can achieve in the co-operation knowing the other parties objectives. Then there is a higher probability to succeed with the individual goals.

- Use of innovative solutions in the process: When working together as a team with understanding of each others problem it is easier to use innovative solutions that will have a good chance to succeed. Every contractor/subcontractor is expert in its own field. To be involved already at the design stages increases the possible innovative solutions for the project. An incentive for innovation is that a bonus often will be shared among the actors if the solution results in a better economy for the production cost.

- Use of benchmarking: It is important to compare with other projects and learn from their success and failures and to bring in methods that would improve the process. Visible objects for benchmarking can be budget performance, total economy, number of defects, customer satisfaction, delays, etc.

- "Open cards": In order for the new type of system to work it is important that all the actors have faith in each other. If everybody works with the open cards attitude where the profit is discussed and there are no secretes between the participants, then the decided solutions will be a gain for all.

- Contractors in the design phase: This plays a central role in these new forms of procurement systems. There are several advantages i.e. the risk is lower, experts in different fields in the negotiate/discuss. It can be hard to administrate the involvement of the subcontractors if they are too many.

- Solutions through dialogue/ discussion between contractors from different areas: The specifications like drawings and details are developed in discussions with the people who are going to carry out the different details of the project. Problems will more often occur on the drawing table than out on site where it is more cost full to make the solutions.

- Life cycle analysis/ Holistic view: It will be a more holistic thinking about both how to produce it and the final outcome. One thing that guarantees that is that it will be the same key people that will be on the building project from start to finish.

SUMMARY

There are similarities as well as differences between Sweden and Denmark and their construction sectors. The two countries have a similar political, cultural and, social structure. Even the minor differences in the two languages do not constitute a barrier for integration. The paper identifies that competition and barriers to entry market are different for SME and large companies. Small companies face no significant barriers to entry the market but have difficulties to compete outside its own local market. Thc bridge will reduce the impediments for a small actor to operate in the opposite country. Accordingly, improved communications will enlarge the boarder of the local market. Large companies, competing for major contracts, primarily need good track records and business relations in order to enter and be competitive on the construction market. This is one explanation to the strategy of the large Swedish contractors for taking over Danish construction companies as a way to enter the Danish market.

Experiences from other border districts show that good communications is not sufficiently enough to promote integration (SBI 1999). The economical incentives must be strong enough for the business actors in comparison to the risk. Further, the benefits must be equal for both countries in order to create a mutual degree of integration. The conditions of taxes, rules and regulations, social security etc become important. Consequently, integration of the Swedish and Danish construction sectors is not only a matter to the business actors but also requires political concordance on a local as well as central government level.

The economic integration through the single market within the EU will affect the construction companies. They must be able to face a greater competition on the local market, but also get the possibility to entry other construction markets within the EU.

There are signals for a series of significant changes within the construction sector. It has already started with the development of new procurement methods that encompass a more holistic view. Contractors and subcontractors work together with "open cards" instead of see each other as antagonists. The customers also get to play a greater role in the early stages of the construction process.

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Construction Procurement and Management in the UK & South Africa: A Comparative Study

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ABSTRACT

Recent case study based research into procurement in the Central Belt area of Scotland in the UK has generated a number of interesting findings associated with management on construction projects. The main finding has been that procurement has now evolved into a state best described as 'post-modern'. Formal procurement systems no longer seem to exist in any recognisable form; instead an infinite variety of procurement systems are generated as clients and professional advisors 'pick and mix' desirable qualities of various systems to make bespoke solutions to their perceived situational requirements. These findings in some regards closely match, and occasionally diverge from the results of a wide ranging survey conducted in the environment of the South African construction industry. While the methodologies adopted by the two studies differed markedly, the similarity in results implies significant movement in the nature and form of procurement and therefore management around the world. This paper therefore compares and contrasts the findings of two very different studies in disparate nations, in order to address the issues of similarity and difference and identify common themes associated with 'post-modern procurement' internationally.

RESEARCH CONTEXT

The building procurement decision making process has been recognised as presenting significant problems to the effective delivery of projects within the time, cost and quality requirement of clients. The highly fragmented, transient, peripatetic nature of the construction team has been highlighted as significant since it places huge responsibility on this team for creating an appropriate organisational system in order to facilitate design, construction process and successful completion of the project. Frequently it is thought that construction is unique among complex · assembly processes (i.e. manufacturing), which prevents the use of best practice from elsewhere. The need to remedy this situation has been a driver in developing new 'Best Practice' (e.g. M4I initiative, Construction Best Practice Panel etc) methods of organising construction following the Egan report (1998). All these issues are now addressed in formulating construction teams to deliver projects within target cost and time. Responsibility for creating an effective construction team in an effective contract system to deliver requirements remains with the client - part of 'the amalgam of activities undertaken by a client to obtain a new building' (Franks, 1984) - i.e. the selection of a procurement system.

Different generic procurement routes have been created to satisfy the diverse requirements of clients. These systems (Masterman, 1992) are defined as: separate/co-operative (e.g. traditional open tendering); integrated management (e.g. D&B) and management oriented (e.g. management contracting). Research indicates clients and advisors select procurement systems illogically and inappropriately (Masterman, 1992) – to an extent that it is a principal reason for poor performance (Skitmore and Marsden, 1988). Benefits and problems associated with each procurement system have been variously reported upon over many years (Banwell, 1964; Latham, 1994). A repeated theme in these reports is criticism of design and construction separation inherent in 'traditional' procurement methods. Egan (1998) recently introduced further dimensions to the procurement puzzle by advocating 'partnering the supply chain' - integrating conflicting needs of design, construction and supply to increase client satisfaction, reduce waste and costs. The implicit criticism remains that selecting procurement route is generally inappropriate and inefficient. Traditional approaches to procurement have evolved organisational structures, which carry with them assumed but, arguably, unproven ideas of roles, responsibilities and communication patterns. As procurement evolves, clarity in role, responsibility and communication blurs. New approaches to procurement do not benefit from previous experience. Clearly one aspect of any procurement process needing careful definition is selection of an appropriate organisational structure as a basis of the development process (Turner, 1990). The task of assembling materials, labour and finance in the right place, time and order to construct a building implies a huge amount of information being passed among project participants. Construction teams therefore spend a lot of time directly in some form of communication, requiring highly-organised communication since effective networks speed information flow and accuracy (Hardcastle, 1992) – increasingly important as sub-contracting, less skilled labour and reduced margins have increased growth in alternate forms of procurement. These trends are justified on grounds of reduced costs, but recently attempts have been made to rationalise the burgeoning supply chain so created. This has manifested itself in the use of a system of preferred suppliers – what are know as 'Prime Contractors' (e.g. BAA Framework Agreement).

Although similar in using 'Prime Contractors', recent PFI (and PPP) procurement methods have created problems in structure and communication pattern. Whichever approach is used, communication networks are essential to project success - allowing organisations to work effectively. Arguably, in traditional procurement, limited sub-contracting and unsophisticated technology allowed networks and communication patterns to evolve. This is no longer the case. Integrating design and construction through D&B and partnering approaches may be unsuitable for all projects. They may be less effective than traditional methods since there is no time to develop consistent patterns of communication. A need remains to define elements and structure of communication networks transferable to all project types. Recent steps taken by large and experienced clients such as the UK Ministry of Defence (MoD) - i.e. the 'Building Down Barriers' initiative (Nicolini, 2001) – could be regarded as 'post-modern' procurement, significant of yet further evolution in procurement systems. The selection of a procurement system by the client largely defines the manner in which communication takes place. Mainstream management authors (e.g. Roberts and O'Reilly, 1978) argue that organisational structure is defined by communication. Weick (1987) confirms its importance to the management structure, when he states '[communication] is the essence of organisation because it creates structures'. Given that the client in conjunction with their advisors select the procurement route, along with an accompanying contract, this in turn creates the formal lines of communication and therefore by definition, the organisational structure. It could be argued that this is in actual fact a 'quasi-structure' since the reality of project communications will tend towards a less rigid social or 'informal' structure. Indeed, the value and importance of this form of communication to the efficacy of the project, and ergo organisational sub-structure, was identified by the Tavistock Institute some time ago (Higgin and Jessop, 1965). Significantly, even the criteria by which it should be possible to objectively evaluate a 'successful' project is difficult. Hewitt (1985) established that each category of clients (experienced, inexperienced, public, private etc) determine project success by different criteria. Hewitt went on to recommend that industry should be aware of, and fully understand, the individual characteristics of groupings in order to assist them in the selection of the most appropriate procurement system for their particular project. Success refers to the extent client's objectives, in terms of time, cost and quality are met. Time and cost dimensions may be quantitatively measured using pre set standards, but quality issues will be perceptual and client determined. One observation becomes immediately apparent after a review of the current state of procurement and communication structures adopted for construction. The problems faced are common both nationally and internationally, and solutions are being sought in parallel around the world. To achieve client time, cost and quality objectives, the basic research discussed in this paper sought to improve the understanding of organizational structures and the decision-making processes associated with each method of building procurement. The research findings are compared with those of a contemporaneous South African study in order to identify areas of cross over and the potential for future joint research.

UK METHODOLOGICAL APPROACH

The original methodological framework for the research saw the construction project as consisting of three decisional and communication domains. These were firstly, the determination of client objectives. Secondly, the determination of the procurement system. Finally, determine the project organisational structure. Given that these domains could be considered to be subsystems within the project in and between which decision and communication takes place, the flow of information and therefore decision-making and communication needs to be timely and effective in order to expedite construction. The methodological approach used in the study was more qualitative than originally intended. Various research tools were selected for use with the case studies. The primary information source was semi-structured interviews of 'elite' members of the construction team members taking part in the projects (i.e. project manager, structural engineer, M&E engineer, QS, architect and contractor). Initially the COMPASS communication assessment tool (Tucker et al, 1997) was used, making a useful comparison between the projects of six critical communication variables – timeliness, accuracy, completeness, understanding, barriers to communication and procedures. Subsequently the researchers returned to each participant to review the progress of the project and assess the communications taking place. The nature of these subsequent interviews became that of retrospective 'story-telling' of the happenings on the project in the intervening period. It was found after an analysis of the preliminary case studies that these 'stories' followed a uniform set of typologies common across all projects. By analysing the frequency of repetition of stories in each of these typologies a histogram 'footprint' was created unique to the project. This allowed objective description of projects in terms of frequency of a project typology. This allowed the researchers to review and amend the epistemology, adapting it for a deeper understanding of the reasons for the pragmatic decisions made.

A set of pilot studies allowed the research team to fully develop a set of research tools that would be used on all the projects forming the body of the work. The pilot projects were also useful in that it was found that in order to be able to develop depth and texture in the data, and also to not lose contact with the rapidly evolving situation on site, realistically no more than 2 or 3 projects should be running concurrently. The numbers of key personnel involved on each project and the diverse geographic locations of their respective offices made travel time a significant factor. Furthermore their time on site was so limited that interviewing at that location was unfeasible. This finding had significant import for the study in that the originally planned sample of 20 case studies became logistically impossible to support by the research team. To maintain the continuity of the effective research techniques applied, it was therefore decided to reduce the overall number of projects in the sample. Therefore a completely new set of projects was selected instead of the originally plan set. In the end a reasonably diverse sample of 12 projects was secured that included a representative cross-section of the various procurement routes available to the modern construction client, including 'traditional', design and build, management and partnered forms of procurement. It is accepted that the sample of projects secured is based on those projects that were willing to participate in the study and cannot therefore be considered to be a randomly based sample. In view of the depth and breadth of access allowed into the projects, this non-randomness was considered an acceptable aspect of the study.

RESEARCH OBJECTIVES

The research sought to achieve the following objectives:-

1. Determine how client objectives are formulated and how they influence procurement system selection.

2. Establish how procurement routes are chosen and relationship with embedded organisational structures.

3. Determine the communication patterns which result from the organisational systems.

4. Examine the decision making processes in each of the above inter-related systems.

KEY FINDINGS

A New Paradigm in Construction Procurement

Research showed that industry is well in advance of academia in being able to adapt to the reality of new construction procurement methods. This is both a new finding and in a very real sense a validation of the Mintzberg contention that industry sets the agenda and academia acts as a recording medium. An analysis of the selection criteria of clients use in conjunction with their advisors showed that the Clients/advisor combination usually select 'correct' procurement method given the normally accepted standards of 'appropriate' procurement route for given client requirements. The Masterman (1992) based analysis tool showed a strong propensity for clients to select the most 'appropriate' procurement method (Tookey et al, 2001). Moreover, analysis of the second and third most appropriate form of procurement in the given project circumstances showed that these secondary and tertiary 'appropriate' methods were addressed using additional contract clauses in the main contract. None of the procurement systems fitted into an easily recognisable procurement system *per se*. The results demonstrate a new paradigm in the description of procurement systems in operation today. Currently it would seem that a 'post-modern' approach to procurement has emerged, an approach that does not fit any of the commonly accepted procurement descriptors, but instead adopts the 'pick and mix' approach to procurement – procurement through 'preferred modalities' of project delivery. Effectively clients and their professional advisors, create unique contracts and forms of procurement suited to the particular circumstances in the project by taking the 'best' (i.e. most pertinent) terms of generic contracts available (Tookey et al, 2001). This implies for researchers that it is impossible to be able to objectively compare the results of two projects that are notionally procured under the 'same' system. This has significant import to the *weltenschauung,* or view of the world, that should be adopted by procurement researchers in the future, since it was opened a new territory for research. Indeed this has highlighted the need to delineate and map this new region.

Novel Understanding of Client Requirements and Procurement Methods

The architecture of a fixed set of client requirements feeding into a fixed, delineated procurement route – historically the standard model for procurement research – does not exist. Client requirements for a project do not fit into any pattern assumed or found by previous research. No case study projects could be fitted into any of the pre-existing procurement 'types'. This resulted from adaptive methods of tailoring procurement to the specifics of problems and requirements on each project. To have attempted to compare the results of two 'identical' procurement methods would trivialise the impact of project specific factors in the outcomes. Very simply, client requirements either gradually (the incremental model) or dramatically (the quantum model) evolved during the life of the project. Each procurement routes therefore became so unique with site specific problems requiring bespoke solutions that 'off the shelf' or 'one size fits all' procurement was never an option. In each case the procurement route 'selected' had in actual fact to be specially created hybrid, incorporating the 'mix and match' principle outlined above. Indeed all participants in the case study projects reported that the original contract had been either moderately or significantly amended to reflect this trend. This challenges the notion of seeking to find generic process protocols for all projects since there is now evidence that each project can and must establish unique protocols reflecting its particular circumstances. This key finding is related to objectives 1, 2 and 3. Indeed, this could be seen as strong evidence to support the notion that procurement is metaphorically more closely related to evolution than to replication. A model in which construction is a metaphorical ecosystem, construction projects are food sources and procurement systems are animals competing for food. The idea can be expanded further to incorporate contractual clauses as the 'DNA' that can be amended, adapted and combined to create an infinite variety of procurement 'animals' to exploit every possible source of food available. The relationships in this system are dynamic, and as such Darwinian competition will mean that certain procurement 'animals' will thrive, others will face extinction. Within each 'species' of procurement, infinite local sub-strains and variations will exist in order to take advantage of particular conditions. As in the ecosystem analogy, procurement 'animals' will never stop evolving while environmental change continues and possible advantages can be achieved.

New Paradigm Procurement Uses Traditional Communication Patterns

Communication patterns demonstrated in the projects appeared to adopt the same accepted and understood network as the 'traditional' method of procurement. This will be the subject of future research. This was as a result of expediency in the fast moving environment of each of the projects. The dilemma faced by participants was either firstly, to observe the protocols of formal communication along prescribed channels, or secondly to speak to the participant with the necessary skill set to get the job done. This second option required the retrospective observation of the formalities of communication (i.e. creating the paperwork covering the decision made or information transferred). Unsurprisingly most participants chose to take the latter approach – producing paperwork detailing decisions after the event in order to maintain the integrity of the audit trail associated with the project. This scenario was most commonly played out on design and build contracts in which novated consultants regularly went outwith the reporting chain of command (i.e. through the main contractor). This key advance is related to research objectives 2 and 3.

A New Generic Project Typology 'Footprint'

An analysis of the interviews in progress discovered a number of recurring themes within the 'stories'. Eventually 14 distinct typologies for stories were identified; these typologies could be grouped by either being 'Project generated' (i.e. specific to decisions taken on the project) or 'Non-project generated' (i.e. external factors impinging on the project that could not be predicted). A further refinement of this concept was to classify incidents as either being enhancing or detrimental to the project. The frequency with which these stories were repeated throughout the project allowed for the development of a frequency histogram or 'footprint' for each project. This was found to be particularly useful in getting an understanding of critical aspects affecting the performance of the project. Looking at the 'footprint' could quickly identify projects in which communication was the biggest problem, or that in which supply chain management created most problems. It is felt that this technique, although in its infancy and needing some development, could provide an extremely useful tool for future researchers analyse organizational structures and performance.

Formal and informal communication structure

A marked difference was found to be evident in the nature and structure of formal and informal communications taking place in the construction team. There appeared to be informal (and therefore unaccountable) communication taking place purely to expedite the unwieldy nature of the formal communication network. There is preliminary evidence that a higher level of formality in communication takes place as a result of problems that are likely to result in litigation (Tookey et al, 2001).

Satisfaction and effectiveness of decision-making

No correlation between the various procurement routes examined in the research and the satisfaction shown by participants and clients in the decisions made was established. This finding is related to research objective 4, showing the efficacy of the decisions emanating from the various organisational structures seen.

South African Study

The achieving optimal project time, cost and quality (TCQ) from a procurement system is as intrinsic to the attainment of client objectives in South Africa as in the UK. To examine this link, the opinions of clients, architects, QSs, PMs, engineers and contractors in South Africa were obtained via a questionnaire survey.

Methodology

The methodology adopted by the South African study differed significantly from the UK study. A stratified mail questionnaire opinion survey was conducted, examining project perceptions and practices of procurement teams in the procurement process. As with the UK study, survey participants comprised clients, architects, quantity surveyors, consulting structural engineers, project managers, and general contractors. Questionnaires were sent to practices and organisations rather than to individuals using professional directories. A total of 180 questionnaires were distributed, comprising 30 from each sub-group. 143 replies were received (79.4%), comprising 10 clients (33%), 24 architects (80%), 30 QSs (100%), 30 engineers (100%), 25 PMs (83%) and 24 contractors (80%). The questions for each group of participants were designed to facilitate an inter-group comparison. Greater reliability attaches to results for the whole sample than to those for individual sub-groups, but the intention of the survey was more to reveal areas of concern for the industry within the procurement system, than to provide hard evidence of inter-group differences.

Survey results

For this study, various procurement systems have been grouped together into three generic forms, namely: conventional (traditional, negotiated, cost-plus); design and build (design and build, package deal, turnkey etc); and management-orientated (management contracting, construction management etc) (Masterman, 1992). The conventional method of building procurement is reported by nearly 70% of respondent clients to be the most widely utilised procurement system. The management-orientated (21%) and design and build (9%) enjoy considerably less usage. The results presented are indicative of the issues raised by the study, and are discussed question by question - comparing participating groups' opinions about each issue.

Question 1: Please indicate whether clients are realistic with respect to expectations of time cost and quality at the outset of the project. (Answer choice = all/most/some/none of the time)

The responses show client and consultant opinions are far from uniform. Clients are relatively sanguine about their TCQ expectations, with a majority believing their expectations to be realistic. The most pessimistic view of clients' TCQ expectations are held by architects, with only clients' quality expectations receiving a majority affirmative response. This is probably attributable to the control over quality which architects perceive themselves to hold as principal agents for the client under traditional procurement systems, as compared to the management of time and cost, for which they would assign responsibility to contractors and quantity surveyors, respectively. A similar response pattern is apparent with engineers and, given their principal role in engineering projects, a similar explanation may hold for their views. Apart from clients, QS hold the next most optimistic view, a clear majority believing clients have realistic expectations about TCQ from the outset of a project. The QS' views are closely matched by those of project managers. The views of engineers are probably influenced by the nature of engineering projects, where quality is made explicit at the outset, but time and cost are more uncertain (eg. schedule of rates and cost-plus contracts for engineering projects). Given that engineering projects often comprise fewer components than building projects, and many engineering projects are commissioned by public sector agencies with substantial experience, this may explain why engineers are more optimistic about realistic client expectations of quality. Contractors are surprisingly optimistic about the reality of client expectations for time and quality. An explanation for this view of project time is not readily forthcoming, given that in most conventional systems, the contract period is not part of the contractor's bid, but stipulated by the client. Similarly, the defects liability period stipulated in most conventional systems suggests client expectation of quality are less than realistic. Contractors' pessimism of client cost expectations is probably explained by their having to seek work in a highly competitive market. Responses for the project time, appear to show most variability. Given clients' practical inability to model time performance reliability, their highly optimistic view of the reality of their own expectations for this factor, at the outset of a project, deserves more thorough research attention.

Parameter	% of respondent groups						
	All	Clients	Architects	QS	Engineers	PM	Contractors
Time	57	90	33	67	47	60	63
Cost	57	70	44	83	41	72	46
Quality	74	80	65	83	59	84	79

Table 1. Extent that clients are realistic in their expectations of project time, cost and quality at the project outset

Question 3: To what extent is an attempt made by the procurement team to match client needs with the characteristics of different procurement systems? (Answer choice: (always/sometimes/never)

Clients have a false perception of the extent to which consultants and contractors will match procurement systems to clients' needs. At best this is done only sometimes. The danger here is not only that clients may not be getting the procurement system which best matches their needs simply because consultants are not fully advising them, but also that clients are believing (erroneously) that they are getting such advice.

	% of respondents groups						
	All	Clients	Architect	QS	Engineer	PM	Contractors
Extent of matching procurement characteristics with clients' requirements	43	67	48	43	37	44	25

Table 2. Extent team matches client need with the procurement system characteristics during selection process

Question 5: What proportion of building projects are completed within the client's agreed budget for the project? (Answer choice = all/most/some/none of the projects)

Engineers appear to be the least optimistic of respondents with respect to the cost performance of projects under design and build and management-oriented procurement systems. As noted under Question 1, this may be due to the preponderance of conventionally-procured public sector engineering projects in professional engineers' workloads. It might be speculated that architects' comparative lack of confidence in the cost performance of management-oriented procurement systems arises out of their unfamiliarity with this system. They may even have confused it with the 'cost plus' form of contract under a conventional system.

Procurement method	% of respondent groups						
	All	Clients	Architects	QS	Engineers	PM	Contractors
Conventional	78	78	75	83	83	75	69
Design and build	77	83	71	76	58	89	94
Management	75	67	54	77	59	95	89

Table 3. Perception all or most projects are completed within the client's agreed budget (building cost) for the project

Question 6: To what extent do clients make changes to the original brief (in respect to time cost and quality) after the start of the project? (Answer choice = always/sometimes/never)

Clients' apparently high regard for their ability to stick to the original brief is clearly not shared by their consultants, nor by contractors. The majority of client respondents believe that variations to the brief only sometimes occur after the start of the project. This finding suggests there is a serious gap between the perceptions of clients and procurement team about what constitutes a variation to the original brief, and that consultants particularly are not successfully communicating the full implications of variations to clients.

	% of respondent groups						
	All	Clients	Architects	QS	Engineers	PM	Contractors
Client led brief changes	62	20	58	67	70	60	71

Table 4. Perception of extent to which clients make changes to the original brief (in respect to TCQ) after project start

Question 7: Do the procurement team utilise a formal brief-elicitation procedure for determining client requirements in respect of the project? (Answer choice = always/sometimes/never)

Lack of understanding about what constitutes a formal brief-elicitation process may explain the responses to this question. Architects and quantity surveyors might have been expected to display far more confidence in formal brief-elicitation procedures for conventionally-procured projects.

Procurement method	% of respondent groups						
	All	Clients	Architects	QS	Engineers	PM	Contractors
Conventional	49	44	57	37	50	54	52
Design and build	54	83	29	38	46	72	72
Management	50	50	27	50	41	65	56

Table 5. Extent that procurement team use formal brief-elicitation to determine client requirements for the project

Question 10: Please indicate the proportion of contracts having cost variations that are significant compared with the original contract amount. (Answer choice =all/most/some/none)

There is little difference between the responses of clients, architects, quantity surveyors and engineers to this question: they appear to believe that choice of procurement system has little influence on subsequent contract variations. Conversely, most project managers, believe that conventional systems yield a higher level of subsequent variations on all or most projects. Curiously, contractors believe this also happens with design and build procurement systems. It is difficult to speculate about why contractors do not believe that a high level of variations occurs with all or most projects procured under management-oriented systems.

Question 13: Please rank the following procurement systems in terms of their ability to facilitate the effective monitoring and control of construction TCQ. (Answer choice: 1 = most; 3 = least effective)

Consultants' suspicions are deep-rooted about the capacity of design-build procurement systems to facilitate effective monitoring and control of construction time, cost and quality. Project managers and contractors, on the other hand, share similar suspicions about conventional procurement systems. Middle ground appears to be available in management-oriented procurement systems, which actually scored best overall in the survey but, curiously, contractors, despite their higher level of involvement in such systems, seem to believe that they are almost as ineffective as conventional systems for monitoring and controlling construction TCQ.

Procurement method	% of respondent groups						
	All	Clients	Architects	QS	Engineers	PM	Contractors
Conventional	40	33	27	23	30	63	67
Design and build	28	17	33	19	38	22	68
Management	30	17	20	35	36	25	33

Table 6. Perceptions of all or most contracts having significant cost variations compared original contract amount

Project parameter	Respondent group rankings (calculated from group response means)																				
	All			Clients			Architects			QS			Engineers			PM			Contractors		
	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M
Time	3	2	1	2	1	3	2	3	1	3	2	1	1	3	2	3	2	1	3	1	2
Cost	2	3	1	1	2	3	1	3	2	1	3	2	3	2	1	3	1	2	3	1	2
Quality	1	2	3	1	3	2	1	3	2	1	3	2	1	3	2	2	3	1	2	1	3

Table 7: Ranking of procurement in terms of ability to facilitate effective monitoring and control of construction time, cost, and quality (N.B. *C = Conventional system; D = Design and build; M = Management systems)*

Question 15a: For the listed procurement systems, please rank the following factors regarding their usual contribution to time over-runs on building projects. (Ranking: 1 = most; 7 = least contribution)

Regardless of choice of procurement system, by far the worst offenders in terms of contributing to project time over-runs are client-induced changes to the project. Other substantial contributors to poor time performance are changes to start dates and the late issue of documentation. It appears from client responses that they are prepared to concede that they themselves are usually to blame for this. Conflict between, or lack of specifications or documents, was seen as less likely to contribute to project time over-runs under management procurement systems than under other systems. External factors such as strikes were perceived as least likely to contribute to project time over-runs, regardless of the type of procurement system used.

Characteristics	Calculated mean rankings of respondent groups																	
	Clients			Architects			QS			Engineers			PM			Contractors		
	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M
Client-induced changes	1	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1
Inclement weather	4	6	6	5	7	6	2	2	3	2	4	4	5	4	6	5	4	4
Conflict between or lack of documents/specifications	5	7	3	7	6	5	7	7	4	5	2	3	4	3	4	3	5	3
External factors (e.g. strikes)	7	3	5	6	5	6	6	3	6	7	6	6	7	7	7	6	6	6
Changes in start dates	2	1	2	4	3	3	5	6	7	3	5	2	2	1	2	4	3	5
Contractor problems	6	5	7	2	2	4	4	4	2	4	3	4	6	6	5	7	6	7
Late issued documentation	1	4	4	3	4	2	3	5	5	6	6	5	3	5	3	2	2	1

Table 8: Ranking of listed factors comparing usual contribution to time overruns under each procurement systems

Question 16: For the procurement systems listed, please indicate the likelihood of effectively controlling the cost of a project at any of the following stages. (Answer choices: good/satisfactory/poor)

As the interpretation of the meaning of the terms ‘good’, ‘satisfactory’ and ‘poor’ was left to the respondents, as was the source of the cost controlling function, the responses to this question should be treated with circumspection. However, certain general observations are pertinent. Insofar as the cost control function associated with conventional procurement systems is concerned, all respondent groups, with the exception of the architects and the QS’, are of the opinion that the likelihood of effective cost control *decreases* as the project enters the construction phase. With the notable exception of the quantity surveyors, similar perceptions are held in regard to the design and build method procurement systems. Clients appear ambivalent in this regard. Insofar as cost management within management-orientated systems is concerned, most respondent groups see the likelihood of effective control diminishing as the project moves from briefing through to construction. QSs see the potential for effective cost control to increase with the passage of time, whilst clients and architects appear not to hold definite views on this issue.

Project stage	% of respondent groups																	
	Clients			Architects		QS			Engineers				PM			Contractors		
	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M
Brief	67	50	33	54	47	53	48	32	17	60	48	60	87	89	91	52	58	72
Pre-construct	67	50	33	54	47	47	39	40	17	60	40	44	48	78	76	35	58	78
Construction	11	50	33	75	20	47	57	45	42	37	38	38	39	39	52	30	53	44

Table 9: Likelihood of effectively cost control at any of the listed stage under the different procurement systems

Project stage	% of respondent groups																	
	Clients			Architects			QS			Engineers			PM			Contractors		
	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M
Brief	44	33	33	38	33	47	33	42	39	50	28	50	70	79	91	39	58	88
Pre-construct	33	50	33	29	27	40	29	45	42	53	36	42	30	53	76	26	42	50
Construct	44	17	17	33	27	47	54	55	71	50	32	46	44	58	67	26	47	50

Table 10: Likelihood of effectively time control on a project at a listed stage under the different procurement systems

Question 17: For the procurement systems listed, please indicate the likelihood of effectively controlling the time of a project at any of the following stages. (Answer choices: good/satisfactory/poor)

The interpretation of the responses to this question are subject to the same limitations identified in Question 16. Opinions vary considerably with respect to the likelihood of the time aspect of building projects being effectively managed under different procurement systems. QS's as a group see the potential for effective time management increasing in the construction phase, irrespective of the procurement system in use. Project managers hold diametrically opposite views, seeing the potential for effective time management to be highest during the briefing stage - again, irrespective of procurement system. Interestingly, engineers see the conventional procurement system as being superior (irrespective of stage) insofar as potential for the effective management of project time is concerned, whereas contractors see the management-orientated system as best suited in this regard. Clients appear to question the superiority of any one procurement system over another. Clearly, clients and their professional advisors are not of like mind when it comes to the attributes of different procurement systems with regard to the effective management of time.

Question 19: Please rank the following procurement systems regarding their capacity for achieving the client's requirements with respect to time, cost and quality. (Ranking: 1 = high; 3 = low satisfaction)

The responses show that clients, architects, quantity surveyors, engineers and project managers are in substantial agreement about the cost performance of the alternative procurement systems. They perceive conventional systems as delivering the highest cost performance satisfaction; and management-oriented systems the poorest cost performance satisfaction. The other area of mutual agreement is in terms of project quality performance, where architects, quantity surveyors, engineers and project managers perceive conventional procurement systems as delivering the highest quality performance satisfaction and design-build systems the poorest. Contractors perceive design-build systems as delivering the highest cost performance satisfaction, but are reluctant to distinguish between any of the three systems with regard to quality performance satisfaction. The greatest variability in respondents' perceptions occurs with respect to project time performance, where only quantity surveyors and project managers exhibit similar rankings for the three systems, believing management systems are able to deliver the best time performance satisfaction.

Project parameter	Calculated mean rankings of respondent groups																				
	All			Clients			Architects			QS			Engineers			PM			Contractors		
	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M
Time	3	1	2	3	1	2	2	1	3	3	2	1	1	2	3	3	2	1	1	2	1
Cost	1	2	3	1	2	3	1	2	3	1	2	3	1	2	2	1	2	3	3	1	2
Quality	1	3	2	2	3	1	1	3	2	1	3	2	1	3	2	1	3	2	2	3	3

Table 11: Ranking of procurement systems by their ability to achieve clients' requirements with respect to TCQ

Question 30: In general, how satisfied are clients with the time, cost and quality management of their projects under the listed procurement systems? (Answer choice: satisfied/dissatisfied)

Parameter	% of respondent groups																	
	Clients			Architects			QS			Engineers			PM			Contractors		
	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M	C	D	M
Time	100	100	100	91	73	80	41	95	91	97	81	92	81	90	86	75	93	94
Cost	78	60	60	96	80	80	62	74	74	93	69	88	81	84	91	75	80	94
Quality	67	40	40	96	47	87	77	42	91	93	50	70	96	79	91	80	67	81

Table 12: Client satisfaction with the time, cost and quality of their projects using the listed procurement systems

DISCUSSION AND CONCLUSIONS

Although differences exist in the ways in which data was recovered in both of the studies outlined in this paper, some significant points of difference and similarity can be highlighted.

Procurement Paradigm

The UK study indicated that procurement could not be categorised according to the 'types' accepted by academics and the industry. In the SA study the commonest form of procurement was the conventional (traditional) approach - interesting given that tables 6 & 7 show conventional systems are least effective in managing a project and most prone to cost variation. In the UK, the traditional contract was similarly popular, however extensive use of contractor designed elements and a willingness to 'mix and match' bits of procurement systems to get the job done. At present the SA model seems to be broadly happy with the performance of the generic procurement systems that are in place – particularly in the conventional system.

Client Requirements and Procurement Systems

The UK study, conducted longitudinally as the projects were underway showed that the one constant in all construction projects was (perversely) the degree of change that took place from the clients original brief throughout the works until final completion. Table 8 demonstrates that this factor is the most common cause of project time overruns. Similarly, Table 4 summarises a question that sought to elicit from respondents the degree to which clients made changes to the brief after the project had started. It is not unsurprising to see that clients only 'put their hands up' to 20% of incidents such as this. This figure is substantially less than the remainder of the construction team members addressed in the SA study. However this phenomenon can be explained with reference to the findings of the UK study. In the UK case studies, the clients did, it is true make changes to the brief of the project after the project had started. However these changes were as a result of external changes in circumstance more than any willingness to confuse matter in the construction team by changing for the sake of change. One of the defining moments in the construction of 3 of the case study projects analysed in the UK was the announcement of the site of the Scottish parliament building in 1999. This instantly raised the performance requirement for all 3 building literally overnight. The key word that the clients are reading in to this particular question is the 'unreasonable' in conjunction with 'changes'. As far as a construction team are concerned, all changes are pretty much unreasonable. The fundamental requirement for all procurement systems must therefore be to be agile enough to be able to adapt to the changing macro-economic and micro-economic realities faced by projects throughout their lifecycle.

SATISFACTION AND EFFECTIVENESS

Clients seem uniformly pleased in the SA study with all procurement system performance with respect of time (table 12) – ranking all systems at 100%. A view largely held by clients in the UK study; the biggest problem in the UK came from cost variability. Contracts in the UK are largely being created so as to reduce (mainly financial) risk to the client. This means that the Guaranteed Maximum Price (GMP) contract has become increasingly popular. The SA study seems to show clients are most satisfied with the conventional form of contract in terms of quality and cost. This was not reflected by the UK findings, which indicated cost variation as the factor causing most problems in the UK. Arguably the history of using 'other' forms of contract in SA is shorter than in the UK and the higher satisfaction derives from the fact that variation is more likely to be anticipated. This argument could be extended to say that the dissatisfaction hinted at by the findings summarised in table 12 come more from higher expectations for 'new' procurement system which are unrealisable. Clients generally believe they are realistic in their expectations of projects – this is the implication of the high scores in table 1 of the SA results. Overall the driving issues in construction in both the UK and SA are similar, however in the UK there has been a concerted effort to make construction more agile by adoption of a post-modern procurement. Mix and match the best ideas is the order of the day. In SA there appears to be an impetus to retain the best practices of conventional procurement to gain the benefit of not 'reinventing the wheel' each time something goes wrong. It would appear that SA is gradually changing as the economy changes. As such it would appear likely that the SA procurement approach will evolve towards a model similar to the 'post modern' UK, as in the past. Indeed as client requirements become more diverse and prone to rapid change during the procurement process it would seem inevitable that change is likely in the more traditionally oriented SA construction industry. Further research conducted between Glasgow Caledonian and UCT will look towards mapping, recording and pre-empting this change.

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VALUE ENGINEERING BENEFITS FOR OVER BUDGET COMMERCIAL PROJECTS

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ABSTRACT

This paper identifies potential areas for value engineering applications to enable otherwise over budget construction projects to proceed. This study encompasses twenty-three commercial projects all in the range of $8 million to $15 million. Based on the results of this study, a model for application of value engineering principles for commercial projects is proposed. The model may also be applied at other locations where commercial buildings within the above range are being planned. Findings from this study will benefit owners, project managers, estimators, and professionals involved in the pre-construction stage of a mid size commercial project. The projects included in this study belong to the category of commercial building projects located in southeastern United States, where the owners would not have proceeded with construction without the application of value engineering options.

INTRODUCTION

Value Engineering (VE) is a professionally applied, function-oriented, systematic team approach used to analyze and improve value in a product, facility design, system, or service. VE is a powerful methodology for solving problems and/or reducing costs while improving performance or quality requirement (Zabor, 1998). By enhancing value characteristics, VE increases customer satisfaction and adds value to their investment. VE can be applied to any business or economic sector, including industry, government, construction, and service. VE is generally used for a long-term business strategy.

Over the last decade, VE applications in the Construction Industry have become increasingly popular in bringing down construction project's cost back into budget. This paper presents a structured approach for applying VE techniques, which can

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then be used as a model to analyze the correlation between the projects' cost percentages and the VE process. VE techniques have been used consistently in the manufacturing industry since the 1940's, but are relatively new to the building industry (Hayden, 1996). The theoretical VE model approach is technically and logically sound and has been shown to be successful when it is applied properly within a cooperative environment and at the early stages of a project (Hyun, 1997). The VE process can lower costs through analyzing operations, maintenance, useful life, replacement costs, initial costs, and balancing design quality with costs cutting measures (Hyun, 1997).

Balancing the design quality requirements, through VE applications without compromising the functional attributes of the project are the main postulates for this study. The projects considered in this study were all value engineered. In each case, either substitutions or use of alternate means (material, method, specification) were used to bring down the initial project cost to fit into the owners budget. The original estimate of a project was based on the specifications that were initially proposed by the designers. All original estimates were subjected to VE proposals, generated by the general contractor, and implemented with the consent of the respective owners. The extent of savings made in each project was examined in detail. The level of detail considered in this study is the relevant division of Construction Specification Institute (CSI). For each project, the amount of savings made under the CSI division was compiled, and has been listed for each project in Tables 1, 2, and 3.

The CSI work breakdown structure was used in this study, because it is the most commonly used method by general contractors for project cost estimation. CSI breaks down the cost of a project into sixteen (16) main divisions. The initial estimated cost break-up data for each project has also been provided in Tables 1, 2, and 3 for comparison purposes.

OBJECTIVE, SCOPE AND BENEFITS

The objective of this paper is to illustrate the application of the VE process to a category of commercial buildings, whose overall budgeted cost lie in the range of $ 8 million to $ 15 million. From the results of this study a model for applying VE strategy to commercial buildings is proposed. Real data from actual construction projects was used to construct the model. The aim of this study was to illustrate the on-going application of VE principles in the Construction Industry. The study also provides information on the variable relationship between budgeted cost of a project and extent of VE options that are practically possible.

Owners need assurance that they are getting the best possible product for their money. It is the contractor's responsibility to give an owner the highest quality product that meets his business objectives and functional requirements. All the projects considered in this study fall in the category of commercial office buildings, with cost ranging between $ 8million to $ 16 million, located in the metro Atlanta area.

This paper presents a model for preparing VE options during the pre-construction and design phases of a commercial building construction process. The model prioritizes possible areas where VE has potential for cost savings and provides a quick reference guide for VE application. This model was developed for competitive contractors using VE strategies to bring over budget projects back into the owner's budget. When a project is stopped, because it exceeds the budget estimate, no one wins. Anyone having an interest in the project loses. Therefore, this model is expected to benefit estimators, project managers, as well as owners to create VE proposals to enable their over budgeted projects to proceed.

RESEARCH METHODOLOGY

Very little has been done to date to measure the extent of VE analysis in the commercial construction industry and to relate that to a specific measurable outcome through a category of commercial projects. This study investigated the correlation between initial cost estimate and VE cost under each CSI division for commercial projects ranging from $ 8 million to $ 16 million. It is extremely important to understand that the VE proposals that compromise the functional attributes of a project (owner's requirements) cannot be implemented. Therefore, only those projects were included in this study, which were initially over-budgeted and the project costs were brought down through successful application of value engineering proposals.

Balancing the design quality requirements, through VE applications without compromising owner's requirements is the main postulates for this study. All the projects considered in this study underwent VE, which was proposed by contractors and approved by the owners. In each case, either means or material substitutions were done or alternate design were used to bring down the initial project cost to fit into the owners budget. The original estimate of a project was based on the specifications that were initially proposed by the designers prior to the involvement of a general contractor. All the original estimates were subjected to VE proposals, generated by a general contractor, and implemented with the approval of respective owners. The extent of savings made in each project was examined to a level of macro-detail. The level of macro-detail, considered in this study, is the relevant division of CSI. The original estimate and the amount of savings made under a CSI division, for each project was compiled.

For example the total contract amount prior to VE for Project 9 was $ 14,831,959.00 and VE brought about a total saving of $ 1,111,000, which amounts to 7.49% of the total price. In case of Project 9 savings could be made in Division 2 ($ 83000), Division 3 ($ 350,000), Division 4 ($ 3000), Division 5 ($ 5500), Division 6 ($ 20,500), Division 7 ($ 30,000), Division 8 ($ 65000), Division 9 ($ 45,000), Division 10 ($ 3500), Division 12 ($ 5500), Division 14 ($21,000), Division 15 ($ 400,000), and Division 16 ($ 79000). The VE Dollar amounts mentioned under each Division present savings for owner, which are possible. "Others" ($ 1,089,162) under the Project 9 indicates the cost associated with general conditions, permits and fees, and in most cases these are not subjected to VE. The total VE amount for Project 9 was $ 1,111,000, which is 7.49% of the Contract amount ($14,831,959).

MISCONCEPTIONS ABOUT VALUE ENGINEERING

VE is just not "good engineering." It is not a suggestion program and it is not routine project or plan review. It is not typical cost reduction in that it doesn't "cheapen" the product or service, nor does it "cut corners." VE simply answers the question "what else will accomplish the purpose of the product, service or process we are proposing?" (Anderson, 1999). VE is the most effective technique known to identify and eliminate unnecessary costs in product design, testing, manufacturing, construction, operations, maintenance, data, procedures, and practices. There are certain important elements that are necessary for a successful VE analysis: (Dell'Isola, 1974)

- A firm commitment of resources and support.
- A clear understanding of the VE process and objectives.
- Performing the VE analysis in the pre-construction and design phases of the construction process.
- Brainstorming of any and all ideas through owner, contractor, and subcontractors.

The proposed model will provide guidelines for applying VE on commercial building in the range of $8 million to $15 million dollars.

PROJECT DEVELOPMENT PHASE IMPACT ON VE DECISIONS

Typically, a VE study can generate recommendations to eliminate ten to twenty percent of the project's construction costs (Anderson, 1999). If the analysis is performed during the design phase, the designer will usually accept about half of these recommendations, usually providing savings of at least three to ten percent. In conducting the VE analysis on all twenty-three projects there was a five-phase approach that was used, these phases are:

Selection Phase

Select the right projects, team, timing, processes, or elements.

Investigation Phase

"Brainstorm", investigate the background information, technical input reports (such as soils, traffic, environment) and field data, function analysis, team focus, and objectives.

Evaluation Phase

Analyze alternatives and results of the Investigation Phase and, through review of the various alternatives, select the best ideas for further expansion.

Development Phase

Collect additional data to thoroughly analyze those alternatives selected during the Evaluation Phase, and to prepare cost estimates and change proposals, which will assure feasibility, if implemented.

Presentation Phase

Prepare a report (VE recommendations), and be ready to make a presentation of the recommended alternatives. In many cases, the way the findings are presented can be as important as the findings themselves.

This five-step approach was found to be very useful in performing a VE analysis and was broken down for easy use and clarification (Anderson, 1999). Pareto's distribution (Fellows, 1997) was also found applicable to VE in a project. Small and relatively inexpensive VE suggestions in the early stage of a project would have substantial impact on the final cost.

Table 1 Value Engineering Data Analysis for Projects 1-8

CSI Division	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8
Division 2-Sitework	$1,025,500	$577,590	$794,316	$1,052,517	$965,238	$909,750	$1,164,933	$983,624
Division 2-VE	$115,000	$32,000	$74,000	$140,000	$92,000	$93,000	$120,000	$100,000
Division 3-Concrete	$3,205,751	$1,274,407	$1,393,202	$2,581,281	$2,100,349	$2,626,391	$3,668,115	$4,472,481
Division 3-VE	$68,000	$20,000	$20,000	$30,000	$25,000	$30,000	$60,000	$66,000
Division 4-Masonry	$0	$296,037	$207,206	$3,633	$271,970	$285,962	$271,450	$26,800
Division 4-VE	$0	$7,000	$3,000	$0	$5,000	$5,000	$5,500	$0
Division 5-Metals	$356,343	$1,141,597	$1,013,446	$138,658	$245,191	$345,256	$254,000	$208,600
Division 5-VE	$5,000	$40,000	$12,000	$1,200	$6,200	$3,000	$5,500	$12,000
Division 6-Wood	$56,883	$126,197	$239,124	$133,410	$115,103	$29,383	$18,730	$92,131
& Pastics								
Division 6-VE	$2,000	$2,600	$4,400	$2,300	$4,800	$0	$0	$4,500
Division 7-Thermal	$203,590	$267,027	$234,354	$124,457	$258,383	$166,855	$221,705	$161,884
& Moisture Protection								
Division 7-VE	$33,000	$31,000	$3,000	$19,000	$36,000	$26,500	$30,000	$27,000
Division 8-Doors	$1,026,407	$893,500	$719,505	$561,329	$737,510	$1,102,780	$961,225	$1,400,569
& Windows								
Division 8-VE	$52,000	$37,000	$40,000	$20,000	$39,000	$47,000	$40,000	$61,000
Division 9-Finishes	$1,059,736	$650,237	$773,154	$788,568	$508,210	$919,354	$1,101,982	$1,469,926
Division 9-VE	$42,000	$55,000	$37,000	$60,000	$32,000	$55,000	$44,000	$80,000
Division 10-Specialties	$72,893	$35,469	$13,038	$42,241	$9,714	$9,105	$89,822	$49,835
Division 10-VE	$1,500	$900	$800	$2,000	$0	$0	$4,000	$3,000
Division 11-Equipment	$0	$0	$0	$0	$0	$0	$61,000	$3,000
Division 11-VE	$0	$0	$0	$0	$0	$0	$0	$0
Division 12-Furnishing	$43,356	$22,350	$21,295	$46,612	$45,015	$57,665	$49,516	$45,150
Division 12-VE	$1,200	$1,000	$800	$3,000	$650	$3,000	$1,100	$1,300
Division 13-Special	$0	$0	$0	$0	$0	$0	$0	$0
Construction								
Division 13-VE	$0	$0	$0	$0	$0	$0	$0	$0
Division 14-Conveying	$162,000	$327,527	$323,372	$237,365	$164,494	$270,303	$270,000	$698,500
Systems								
Division 14-VE	$0	$9,500	$9,000	$5,500	$0	$5,000	$0	$25,000
Division 15-Mechanical	$1,577,425	$1,250,957	$1,204,022	$1,248,773	$1,457,846	$1,316,189	$1,920,240	$2,238,130
Division 15-VE	$250,000	$108,000	$95,000	$112,000	$233,000	$165,000	$320,000	$430,000
Division 16-Electrical	$925,925	$657,998	$569,174	$535,776	$768,238	$757,049	$1,036,320	$1,028,400
Division 16-VE	$88,000	$56,000	$41,000	$43,000	$63,000	$70,000	$80,000	$92,000
Other	$1,390,976	$718,108	$594,782	$685,371	$1,005,216	$1,092,544	$1,549,222	$1,190,452
Contract Amount Total	$11,106,785	$8,239,001	$8,099,990	$8,179,991	$8,652,477	$9,888,586	$12,638,260	$14,069,482
VE Amount Total	$657,700	$400,000	$340,000	$438,000	$536,650	$502,500	$710,100	$901,800
VE (% of Total)	5.92%	4.85%	4.20%	5.35%	6.20%	5.08%	5.62%	6.41%

Table 2 Value Engineering Data Analysis for Projects 9-16

CSI Division	Project 9	Project 10	Project 11	Project 12	Project 13	Project 14	Project 15	Project 16
Division 2-Sitework	$779,857	$937,062	$1,250,641	$1,125,364	$650,854	$999,974	$2,891,342	$1,500,420
Division 2-VE	$83,000	$96,000	$140,000	$140,000	$57,000	$107,000	$292,000	$180,000
Division 3-Concrete	$5,116,430	$3,011,435	$1,144,944	$1,356,268	$2,641,650	$3,050,901	$3,704,907	$3,669,888
Division 3-VE	$350,000	$58,000	$15,000	$20,000	$28,000	$65,000	$280,000	$310,000
Division 4-Masonry	$161,319	$0	$0	$0	$0	$15,000	$0	$286,766
Division 4-VE	$3,000	$0	$0	$0	$0	$0	$0	$6,000
Division 5-Metals	$300,741	$287,077	$1,207,912	$356,255	$121,900	$3,555	$214,567	$342,128
Division 5-VE	$5,500	$7,000	$44,000	$8,000	$6,000	$0	$7,800	$9,000
Division 6-Wood & Pastics	$301,138	$81,173	$54,778	$65,250	$72,770	$52,845	$52,479	$205,046
Division 6-VE	$20,500	$7,300	$6,000	$6,000	$5,000	$2,000	$5,800	$19,000
Division 7-Thermal & Moisture Protection	$209,523	$233,476	$380,818	$278,960	$134,729	$98,052	$273,779	$176,941
Division 7-VE	$30,000	$36,500	$53,000	$38,000	$22,000	$12,000	$36,000	$31,000
Division 8-Doors & Windows	$1,373,414	$1,143,434	$754,416	$864,580	$649,179	$69,156	$588,341	$2,201,482
Division 8-VE	$65,000	$50,000	$41,000	$60,000	$20,000	$0	$28,500	$92,000
Division 9-Finishes	$1,268,560	$959,391	$739,926	$845,000	$711,300	$689,678	$906,251	$1,547,499
Division 9-VE	$45,000	$38,000	$40,000	$52,000	$27,000	$20,000	$40,000	$52,000
Division 10-Specialties	$54,439	$85,191	$43,489	$56,250	$30,000	$30,636	$53,788	$42,065
Division 10-VE	$3,500	$9,000	$2,500	$2,500	$700	$1,200	$3,500	$3,000
Division 11-Equipment	$716	$233,107	$41,236	$22,000	$0	$2,501	$0	$7,000
Division 11-VE	$0	$0	$0	$0	$0	$0	$0	$0
Division 12-Furnishing	$47,715	$0	$8,000	$9,200	$10,705	$6,744	$0	$90,995
Division 12-VE	$5,500	$0	$0	$0	$0	$0	$0	$9,600
Division 13-Special Construction	$0	$0	$0	$0	$0	$0	$0	$0
Division 13-VE	$0	$0	$0	$0	$0	$0	$0	$0
Division 14-Conveying Systems	$820,494	$384,500	$90,000	$125,000	$315,000	$332,067	$387,000	$810,000
Division 14-VE	$21,000	$8,500	$0	$0	$9,200	$8,500	$7,300	$30,000
Division 15-Mechanical	$2,231,147	$1,553,844	$1,436,501	$1,580,965	$1,726,000	$1,255,423	$1,417,974	$2,330,150
Division 15-VE	$400,000	$250,000	$157,000	$164,000	$255,000	$135,000	$162,000	$397,000
Division 16-Electrical	$1,077,304	$702,881	$751,027	$826,950	$560,000	$694,554	$869,704	$1,275,000
Division 16-VE	$79,000	$58,000	$57,000	$70,000	$40,000	$48,000	$71,000	$84,500
Other	$1,089,162	$916,133	$691,601	$865,234	$1,025,569	$721,953	$965,158	$1,487,443
Contract Amount Total	$14,831,959	$10,528,704	$8,595,289	$8,377,276	$8,649,656	$8,023,039	$12,325,290	$15,972,823
VE Amount Total	$1,111,000	$618,300	$555,500	$560,500	$469,900	$398,700	$933,900	$1,223,100
VE (% of Total)	7.49%	5.87%	6.46%	6.69%	5.43%	4.97%	7.58%	7.66%

Table 3 Value Engineering Data Analysis for Projects 17-23

CSI Division	Project 17	Project 18	Project 19	Project 20	Project 21	Project 22	Project 23
Division 2-Sitework	$1,196,365	$1,245,051	$777,030	$499,829	$880,043	$1,203,848	$1,220,610
Division 2-VE	$124,000	$140,000	$82,000	$57,000	$85,000	$132,000	$118,000
Division 3-Concrete	$2,776,483	$2,303,467	$1,506,680	$4,327,478	$3,912,892	$3,088,513	$3,138,094
Division 3-VE	$57,000	$52,000	$34,000	$110,000	$66,000	$55,000	$50,000
Division 4-Masonry	$7,146	$152,144	$80,650	$283,372	$250,140	$0	$13,000
Division 4-VE	$0	$4,250	$3,000	$5,100	$5,800	$0	$0
Division 5-Metals	$250,000	$1,954,553	$1,620,752	$473,564	$304,687	$178,530	$458,968
Division 5-VE	$8,000	$23,000	$20,000	$6,500	$4,000	$3,000	$5,200
Division 6-Wood	$76,697	$200,762	$73,343	$134,346	$120,456	$183,485	$128,172
& Pastics							
Division 6-VE	$4,200	$8,000	$4,500	$6,300	$4,300	$6,000	$3,000
Division 7-Thermal	$157,427	$443,056	$130,270	$491,395	$105,485	$178,595	$179,939
& Moisture Protection							
Division 7-VE	$22,000	$60,000	$20,000	$66,000	$13,000	$25,000	$28,600
Division 8-Doors	$532,989	$1,461,662	$763,279	$1,223,232	$1,096,437	$723,209	$1,083,326
& Windows							
Division 8-VE	$31,000	$72,000	$40,000	$62,000	$44,000	$35,500	$49,000
Division 9-Finishes	$814,757	$1,353,622	$758,563	$406,906	$1,034,538	$885,651	$1,048,250
Division 9-VE	$40,000	$70,000	$33,000	$1,800	$60,000	$41,000	$52,000
Division 10-Specialties	$22,453	$126,470	$37,750	$115,876	$54,167	$60,227	$45,127
Division 10-VE	$1,200	$6,000	$1,800	$5,500	$4,100	$5,000	$3,200
Division 11-Equipment	$0	$20,802	$0	$0	$0	$2,625	$203,262
Division 11-VE	$0	$0	$0	$0	$0	$0	$13,000
Division 12-Furnishing	$25,582	$103,109	$75,946	$77,000	$40,000	$37,000	$50,831
Division 12-VE	$1,100	$8,500	$3,000	$5,500	$4,000	$2,000	$3,100
Division 13-Special	$0	$0	$0	$0	$0	$0	$0
Construction							
Division 13-VE	$0	$0	$0	$0	$0	$0	$0
Division 14-Conveying	$244,506	$579,646	$271,500	$677,800	$695,570	$437,694	$187,825
Systems							
Division 14-VE	$5,000	$10,000	$4,400	$9,000	$8,400	$5,500	$0
Division 15-Mechanical	$1,042,840	$2,680,347	$1,101,456	$1,641,111	$1,872,464	$1,439,400	$1,458,684
Division 15-VE	$117,000	$525,000	$128,000	$300,000	$350,000	$252,000	$270,000
Division 16-Electrical	$601,783	$110,120	$756,000	$929,348	$715,819	$681,793	$816,970
Division 16-VE	$46,000	$96,000	$61,000	$91,000	$70,000	$43,000	$77,000
Other	$605,953	$1,361,078	$900,918	$1,815,003	$1,346,803	$807,515	$1,139,348
Contract Amount Total	$8,354,981	$14,095,889	$8,854,137	$13,096,260	$12,429,501	$9,908,085	$11,172,406
VE Amount Total	$456,500	$1,074,750	$434,700	$725,700	$718,600	$605,000	$672,100
VE (% of Total)	5.46%	7.62%	4.91%	5.54%	5.78%	6.11%	6.02%

DATA COLLECTION AND ANALYSIS

Data collection was done in a manner to develop a systematic approach for evaluating job costs percentages and their correlation to VE concepts. Before applying VE, items of potentially low value and high cost must be isolated. This identification process is the "art" of the VE approach. There are some 3000 to 5000 cost items involved in a modern facility. To find those few items or areas that represent the bulk of the unnecessary costs is not easy. Using a number of techniques such as breakdown analysis, cost models, functional analysis can facilitate this task, analysis of previous study areas, and study of life cycle cost impact. (Dell'Isola, 1974).

For the purposes of this study cost breakdown analysis was used. Developing the framework for this breakdown analysis was accomplished by first, breaking the project's cost down into the sixteen CSI divisions. Secondly, determining the percentages of each division according to the overall project cost. And lastly, determining which divisions had the greatest amount of VE alternatives and comparing the cost of the two components. As can be seen from Tables 1, 2, and 3, the divisions that were the largest percentage of the overall project directly correlate to the areas that have the greatest impact for VE.

This study encompasses twenty-three commercial buildings all in the $8 million to $15 million range. All of the buildings sampled are constructed at the job site using either cast-in-place concrete or structural steel components. The majority of the buildings in this study include parking decks, which usually cost around forty-percent of the overall building cost. However, in this study the parking decks are not included because there is little VE potential. Very little published literature could be found on the subject of VE applications to commercial projects. Most of the literature on VE discussed strategies and evaluation methods for VE. The majority of the actual data in this paper comes from Atlanta based construction companies. All data used in this research is considered privileged information. In order to keep the name of companies and their projects confidential projects have been assigned numbers instead of names.

RESULTS

Tables 1, 2, and 3 provide cost breakdown data, for each project, into sixteen (16) CSI divisions. In addition, the tables also provide total contract amount, and the savings realized in each division as a result of VE. VE amount as a percentage of the overall cost of the project is also provided in these tables. All twenty-three projects included in this study were able to proceed as a result of the VE analysis. In some cases the owner was able to come up with additional funding which allowed the project to proceed; nevertheless, many of the VE ideas were incorporated into the project design.

In 100% of the projects, VE was suggested and used to decrease the cost of the buildings. Around 92% of these projects were negotiated jobs in which the general contractors were able to work very closely with the owners to meet their needs and bring the project within budget. Study of Tables 1, 2, and 3 reveal that there is a direct correlation between high dollar divisions and areas where contractors should apply VE.

As mentioned in *Value Engineering: Paradigm or Paradox*, Howard McKew states, "The largest value-added target is traditionally HVAC." Some good examples of VE ideas for Division 15-HVAC are: Use rectangular ductwork in lieu of spiral ductwork. Reduce the number of VAV boxes. Use a less expensive HVAC system than the one specified. These ideas hold true for this study because in the projects sampled, HVAC design was the largest area for VE potential on all twenty-three projects. Please also note that Division 3- Concrete maintains a high cost value because majority of the buildings are concrete structures where there is little room for VE.

The Tables 1, 2, and 3 clearly illustrate that from preliminary examination of cost break down of a project, one can identify potential divisions and limitations for preparing VE proposals.

CONCLUSIONS

Results of the analysis carried out in this study show new insights regarding VE options and limitations for commercial building projects. The study certainly shows there is no reason for a construction project not to proceed because it is over budget. The results found in this study demonstrate that substantial savings potential exist through the application of VE techniques in the construction industry. The best place for VE future application is the place where the most funds are being expended. This VE study also identified potential areas where a higher probability for VE is likely and impact possible on project's estimate.

In case of projects that are below the $ 8 million range, the scope and special requirements are clearly defined in most cases. There is a specific functional performance attribute of the building. The owner and or developer know exactly what they want and the purpose of the building. There are limited alternatives such as systems or materials, within the specific price range, that can be used with a particular project in that price range. In most cases, the construction firms deal with parametric cost estimates such as costs per square feet, therefore the VE proposals need to coordinate with parametric estimates of the building.

In cases where the project costs are above the $ 15 million mark there is more room for VE based on dollars per square feet because the buildings are bigger and they are usually designed in much greater detail. Quite often, substantial scope reduction is possible, which may be due to over design or some other reason. There are cases, however, where the project is serving a specific function, for instance a building with heavy mechanical and electrical equipment may require thicker slabs to support the equipment. The thicker slab will drive the parametric costs up and, therefore, it becomes more difficult to achieve substantial savings through a VE exercise.

On many projects in the metro Atlanta area, the architects design the buildings with a pre-cast skin. There are numerous ways to value engineer the design of pre-cast concrete. For Example, if a building has an arcade with column wraps, the pre-cast manufacturer may be able to cut costs by increasing the size of the panels. Increasing the size of the pre-cast panels can make substantial savings. Also larger number of typical pre-cast panels could result in appreciable savings through mass production. When a pre-cast manufacturer has to cast a lot of small-specialized panels, the costs of production increase. Cost of glass panels also vary in a manner similar to the pre-cast panels. These examples illustrate the impact of alternate VE proposals for nonfunctional aspects of a building.

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The Role of the Construction Sector in Highly Developed Economies

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ABSTRACT

Using OECD input/output tables, this paper analyses the performance of the construction sector of nine highly industrialised countries in the Seventies and Eighties. A set of simple indicators is used for comparative purposes, namely to assess the construction sector's diminishing role in terms of share of gross output, value added and GNP. Analysis focuses also on technologies, with emphasis on the relative role of manufacturing and service inputs. Lastly, standard measures of linkages are used to determine the main sources of induced output that are created by the interactions of the construction sector with the rest of the economy.

INTRODUCTION

This paper examines the construction industry of several highly developed countries, its interactions with the rest of economy over a period of approximately twenty years, and how these interactions have changed over time and differ from country to country. The study builds upon a series of input-output data that span the Seventies and Eighties. Comparative longitudinal studies of construction sectors in different countries, particularly their technologies, are not new in the domain of input-output analysis (Bon and Pietroforte, 1990; Bon, 2000). This study expands the set of previously examined industries by comparing the construction sector of eight OECD countries, Australia, Canada, Denmark, France, Germany, The Netherlands, Japan and the USA. The comparison aims at verifying whether the construction sector of the first six listed countries shows trends that are similar to those previously observed in Japan and the USA. The comparison is based on economic indicators in current and constant prices. Their simultaneous consideration is useful to assess the impact of relative price changes that cannot be detected by using only current prices, as in the case of the above-cited studies. The construction sectors are examined, first, in terms of their shares in gross national product and gross national income. Next, the construction technologies are analysed, with emphasis on the changes of the manufacturing and service sectors' inputs, to assess the issue of de-industrialization hypothesis.

Lastly, the nature of linkages of construction sectors is addressed. Standard measures of backward and forward linkages are used to show their push and pull potential. Although our discussion refers also to indicators at current prices, only those in constant prices are presented in graphic form, because of the editorial limitations of the paper.

DATA

In this paper we use the OECD input/output database developed by the Economics Analysis and Statistics Division of the OECD Directorate for Science, Technology and Industry (OECD, 1995). To our knowledge this data set is the most comprehensive source for comparing structural changes in construction industries internationally. The database consists of the data of 10 countries in current and constant prices. Depending on country, time coverage spans from 1969 to 1990. Italy and UK were not considered because of lack of comparable data and consistency in the compilation of tables. The use of data in constant prices avoids the occurrence of problems that are generally created in inter-temporal technology comparisons by non-uniform inflation, a typical phenomenon of the Seventies and Eighties. The original thirty-six-sector tables were aggregated into seven-sector tables. The sectors are: agriculture; mining; construction; manufacturing; trade and transportation; services and other (the last category consists of government enterprises, scrap second hand goods). Data are expressed in producers' prices, with the exception of Australia and Denmark, whose data are drawn from a basic price valuation. The criteria for developing the used economic indicators are not discussed in this paper. In this regard, the reader should refer to Bon (1988).

SHARES IN GROSS NATIONAL PRODUCT AND INCOME

Figures 1 and 2 show the contribution of the construction sector to the gross national product (GNP) and income (GNI) of the eight selected countries. Both shares decline over the examined period, as expected in highly developed economies. The decline is more pronounced in constant than current prices, particularly in the case of Japan. In the Eighties the pace of decline slows down and is reversed in some countries. This phenomenon should be further investigated to verify the hypothesis that relative price changes, e.g., increased construction prices, have partially counterbalanced the decrease of the sector's share in GNP and GNI.

It should be noticed that the average values of these two indicators differ significantly. The construction industry, in fact, produces very little for intermediate use since it consists of two sub-sectors: new construction, and maintenance and repair construction. The former delivers only to final demand, while the latter produces for intermediate use. This fact explains why gross national product shares are larger than those of national income. As stated before, the time profiles of GNP and GNI indicators are characterised by declining paths. In explaining these patterns it was previously argued "that the decline of the construction sector sets in with economic maturity: the more developed an economy, the smaller the construction sector" (Bon and Pietroforte, 1990). Our data set, composed of six additional advanced economies with different sectoral composition, supports this argument. The relatively high GNP share of Japan is probably caused by particular local economic situations, namely government investments and the speculative real estate bubble that burst in the early Nineties.

The different values of the indicators, in addition, suggest that construction does not have a high economic propulsive role in countries such as Germany and The Netherlands. A similar trend starts appearing in France and Denmark in the late Seventies. In other countries, e.g., Japan, Canada and Australia, construction is still an important engine for economic growth.

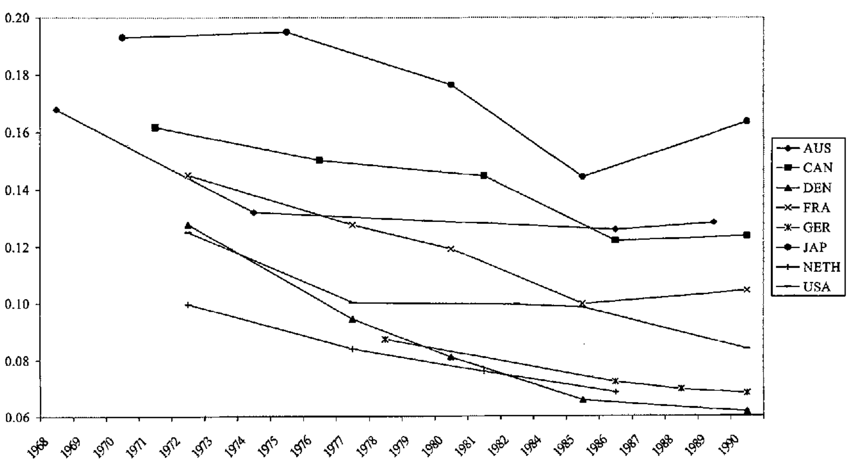

Figure 1 Shares in gross national product

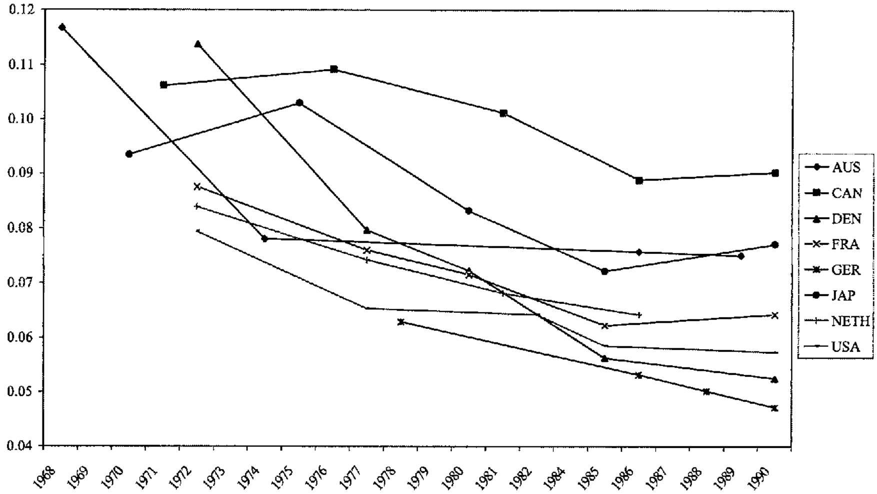

Figure 2 Shares in national income

National construction technologies

The comparison of simple structural indicators is useful in verifying whether technologies (i.e., all the inputs the construction industry needs for producing a facility) vary from country to country. The direct backward linkage indicator, by showing how national technologies differ in terms of intermediate and value added inputs composition, is a rough measure of the industrialisation of a given construction industry. Figure 3 shows the time profile of these indicators in constant prices. As expected, highly industrialised countries show a direct backward indicator that is larger than 0.5. At current prices the overall average of the indicators remains stable from the beginning to the end of the examined period. When constant prices are considered, a different picture emerges. All indicators, with the exception of those of Japan and Canada, show a sizeable increase. We can conclude that price differentials among intermediate inputs and valued added components and the extent of off-site manufacturing are the primary hypotheses to be tested (with more specific data) for investigating such a phenomenon, particularly the case of the USA.

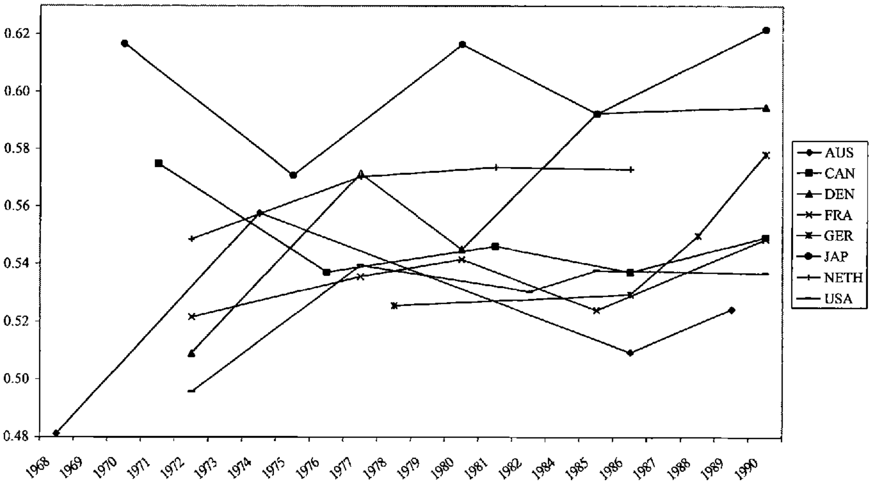

Figure 3 Backward linkage indicators

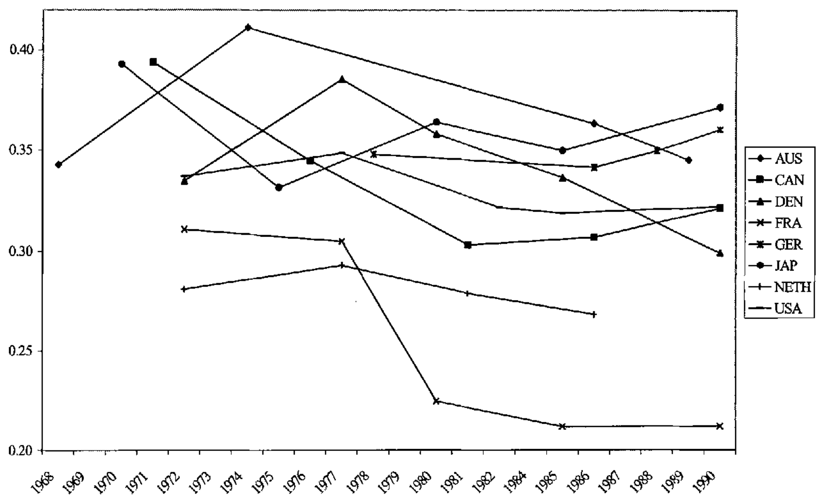

Figure 4 Direct inputs from manufacturing

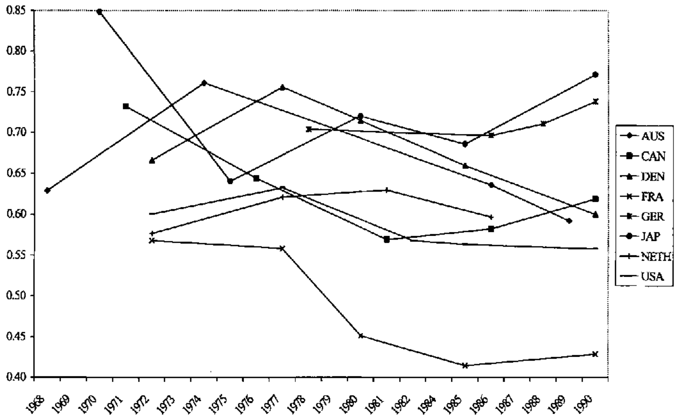

Figure 5 Total inputs from manufacturing

Figures 4 and 5 show direct and total manufacturing inputs to each construction sector respectively. Their time profiles shed some light on whether the construction sectors have changed their inputs and whether there has been a sort of "convergence" in national production functions. Both charts show a steady decline of manufacturing inputs that reach an average direct contribution of 32% in the late Eighties, approximately a 2% reduction since initial observations. Price differentials slow down this trend if both indicators at current and constant prices are considered. The overall parallelism of the indicators with their reduced variability over the years underlines a more homogeneous use of inputs, as expected in highly developed economies. Most construction sectors, in addition, show a contraction of indirect manufacturing inputs. This phenomenon can be interpreted as a sign of the reorganization of the manufacturing sector and/or of the weakening impact of construction investments.

Direct and total inputs from (private) services are shown in Figures 6 and 7. The time profile of their value shows a constant upward trend during the examined period with a significant growth acceleration of some countries, e.g., Denmark, France and Germany, in the Eighties. The final average increase of these indicators more than counterbalances the slack left by the shrinking manufacturing inputs. It should be clear, however, that services cannot replace manufacturing as the main supplier of the building industry. Although the share of services inputs may be as large as that of manufacturing, as in the case of France in the Eighties, and

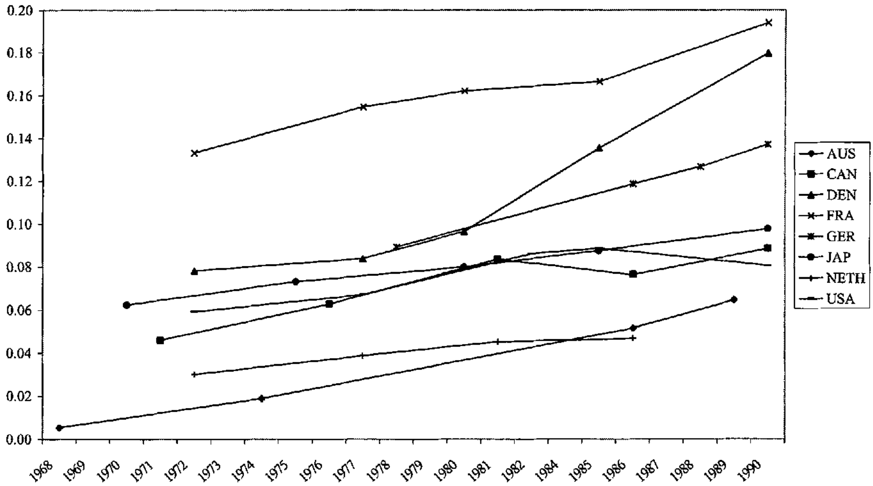

Figure 6 Direct inputs from services

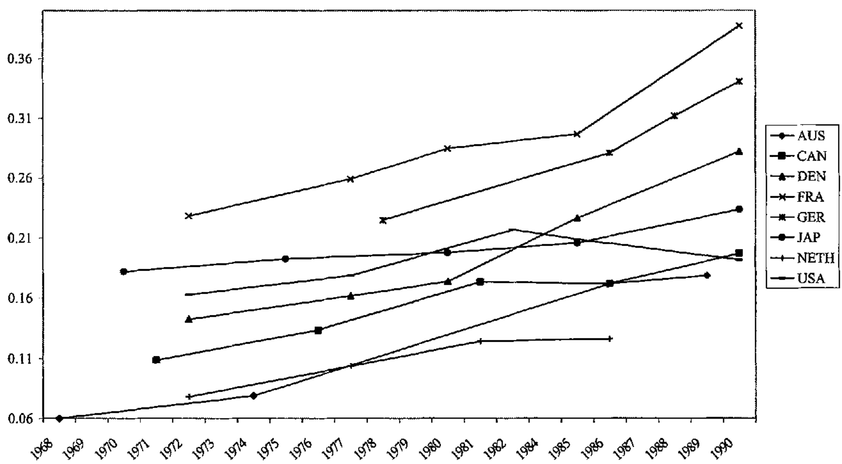

Figure 7 Total inputs from services

manufactured goods are no longer the only relevant supplier of construction in most countries, we should not forget that material inputs cannot be completely substituted with services, such as design, financial, legal or other professional services (Bon, 1992). In this regard future studies based on import data should asses the hypothesis of outsourcing, given the global growing trade of construction products in the Eighties.

A possible explanation of the increasing share of service inputs can be found in the fact that the considered construction sectors have outsourced previously in-house performed service oriented activities from specialised firms and that the increasing complexity of the construction process has demanded more specialized contributions. Modern construction, in fact, needs an increasing number of knowledge- based services.

STANDARD MEASURES OF LINKAGES

Figure 8 shows total backward linkages or output multipliers respectively in actual and constant prices. These indicators show the effect of one unit change in final demand of the construction sector on the total output of all sectors. The construction sector generally has one of the highest total backward linkage indicators among all the sectors of a national economy. The high amount of intermediate inputs reflects the nature of construction operations involving the assembly of many different products purchased from a large number of industries. Periodic stimulative government policies are based on the fact that these "pull effects" on the economy as a whole are among the highest. In current prices the indicator profiles converge downward toward

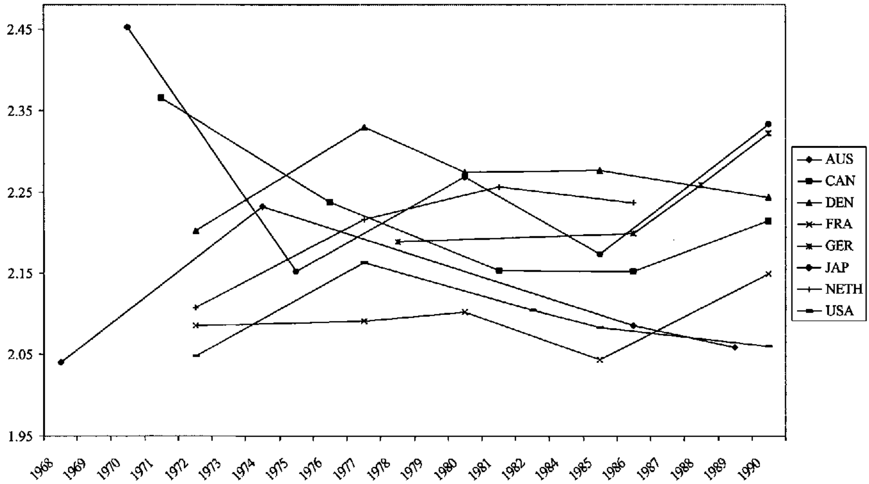

Figure 8 Output multipliers

an average value of approximately 2.12 in the late Eighties. When constant prices are considered, most indicators increase their value with an overall average of 2.24 over the same period. It can be concluded that indirect demand generated by construction investments is somewhat underestimated in standard analyses since data at current prices are generally used. The upward trend of these indicators in the late Eighties probably reflects technological change and reorganisation of the construction industries' modus operandi. Differences among national indicators can be explained in terms of diverse levels of industrialisation of the construction process from country to country, that is, the varying degrees by which the construction and manufacturing sectors are interconnected. Figure 8 shows two distinct groups of countries: Japan, Germany, The Netherlands and Denmark with relatively higher output multipliers and the remaining countries with lower output multipliers. The advanced process of de-industrialisation of the United States, with a shift from manufacturing toward services, could explain the low value of this indicator.

Technologies, in addition, can be differentiated according to small direct or total intensities. The latter tend to perform poorly when all induced effects are taken into account. In the case of The Netherlands and Japan the performance of the total backward indicator is lower than that of the direct backward indicator, while the opposite holds in Germany. This pattern is due to the circularity process implicit in the Leontief model that can be captured by several indicators (Gregori and Schachter, 1999).

Let us now consider the "push effect" of the construction sector, that is, direct and total forward indicators. As shown in Figure 9, the direct forward indicator is the ratio between intermediate deliveries and total output. In Figure 10 the total forward indicator, or input multiplier, indicates the effect of one unit change in value added by the construction sector on total output of all other sectors. Direct forward linkages have a low value and their time profiles show stability during the observed period. As stated before, the construction sector produces intermediate goods and services only through its maintenance and repair sub-sector. It should be noted that the latter is generally underestimated in national income accounts because a significant part of its activities is underreported and/or performed on a force account basis (Bon and Pietroforte, 1993). Capital repair work (a sizable component of infrastructure related projects), in addition, is accounted for as a part of final demand, according to standard accounting conventions. These characteristics explain the low values of the indicators of Figure 9. Within the set of considered countries, Australia, France and Japan show significantly below average values, notwithstanding the large size of their building stock and infrastructure systems. The indicators of the Netherlands, Denmark and, partially, the USA show the strength of the maintenance and repair sub-sector in the construction industry of these countries. When the effect of forward indirect effects is considered, a slightly different picture emerges. Some patterns are strengthened and two different groups of countries can be noted. At the top of the ranking, the time profiles of The Netherlands and, at the bottom, of France and Japan show an almost identical trend for both direct and total forward linkages.

On the contrary, and in the case of Denmark and Germany, indirect effects push the time profile of total effects in an upward direction. This pattern suggests that sectoral interrelations are the main cause of these differences (Gregori and Schachter, 1999).

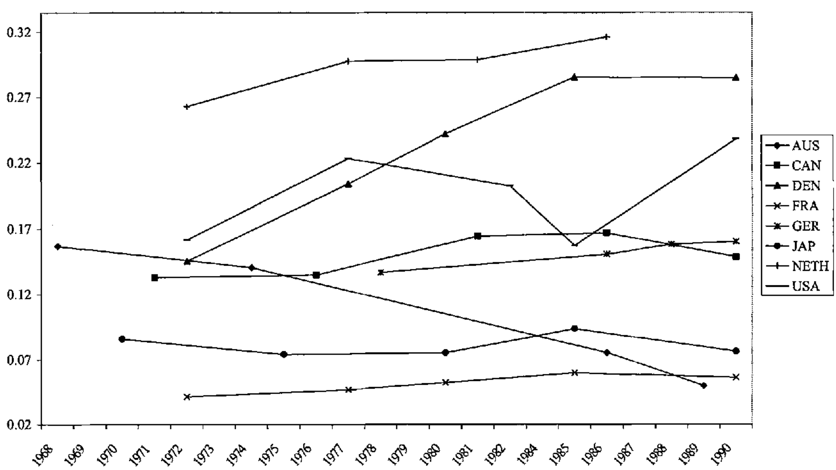

Figure 9 Forward linkage indicators

CONCLUSIONS

Similarly to the findings of the above-mentioned studies about highly developed economies, the construction industry of the examined countries, Australia, Canada, Denmark, France, Germany and The Netherlands, shows a declining role in the national economies during the considered period. The sector follows the economic destiny of manufacturing, its primary supplier and key source of demand for

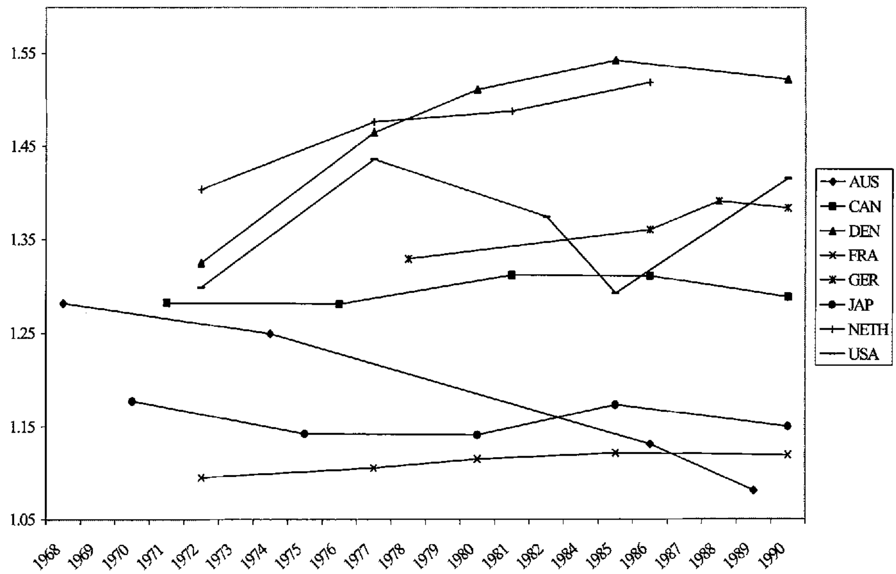

Figure 10 Input multipliers

construction services and goods, whose bell shaped pattern of industrialisation and de-industrialisation is well known (Maddison, 1987). The period under scrutiny, the Seventies and Eighties, follows the post WWII phase of rapid growth in manufacturing and construction with a significant accretion of capital stock. This expansion was followed by a decreasing contribution of new construction and the growing importance of the maintenance and repair sub-sector. In this last regard, the USA is the economy to watch. The increasing size of its maintenance and repair sub-sector in the late Eighties reflects the increasing obsolescence of its infrastructure. A similar phenomenon should occur soon in the other examined countries whose infrastructure development follows that of the USA. The study, in addition, has shown that the use of constant prices is useful to detect patterns that are not detectable with input-output tables in current prices.

The direct backward indicator, for example, deserves additional studies with specific inflation factors (e.g., construction prices, labour and material costs) to assess whether the increased level of "industrialization" indeed reflects a change in intermediate inputs or, more simply, price differentials with no effect of the structure of the production process. The push and pull effects, as revealed by backward and forward linkage indicators, have been quite flat over the examined period, with some exceptions. The construction sector in some countries, such as France and Australia, has a small propulsive role, while in others, Denmark and Germany, it has a larger impact. Finally, in Japan the total backward index shows a high pull potential and a low push effect, while the reverse holds in the USA.

The picture that emerges from this analysis suggests that construction does indeed follow the economic destiny of manufacturing. Future studies should assess how production functions have changed and verify whether there has been a substitution of domestic manufacturing inputs with imported inputs. The increasing share of service inputs shows changes in the composition of assets in the examined economies. Intangibles assets (i.e., knowledge based services), in fact, have grown faster than tangibles and material goods.

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The Challenges to Construction Industry Development in Uganda

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ABSTRACT

The Ugandan government has continued to work towards a fully liberalised economy from the late eighties when the liberalisation policy was adopted up to today. The implementation of liberalisation and other attendant policies for example privatisation has had varied and far-reaching impact on all sectors of the economy including the construction industry. The effect of liberalisation on construction industry performance in Uganda is not exactly known. It is important to measure and characterise this impact by examining the changes and relative trends in the construction supply chain. This would help establish performance indicators and trends for the construction industry and also establish a quantitative measure of the importance of the private and/or informal construction sectors in Uganda. These industry-specific performance indicators form a basis for better and well-focussed policies and strategies for Construction Industry Development (CID). This paper attempts to outline a basis and theory for CID in Uganda basing on the principles of the systems theory.

BACKGROUND

Uganda is an East African country of 241,038 KM^2 total surface area of which 197,097 KM^2 is under land and 43,941 KM^2 is under water and swamps. It has a current total population of 22.8 million (estimate) which is expected to grow at 2.6% per annum to 32.5 million by 2015.

The Gross Domestic Product (GDP) is currently Uganda Shillings 9.684 trillion which is an equivalent of US$ 6.436 billion. The per capita GDP is approximately US$ 280 placing Uganda among the least developed countries of the world. The GDP growth rate is currently 6%. The construction industry contributes 8.5% in monetary terms and 12% in total production terms. Therefore the size of the construction industry in Uganda is about US$ 770 million per annum (MOFPED, 2001).

In the late 1980's Uganda liberalised her economy. The shift in economic policy has been characterised by among other things: abolishment of foreign exchange market control, divestiture of government from business, liberalisation of construction, public sector reform, decentralisation, etc. The change in policy presents some real and major challenges to the recent effort by government towards CID. The government of Uganda is currently developing a policy, strategy and action plan for capacity building of the Local Construction Industry (LCI). In this policy document government identifies three major issues in the construction industry that shall be addressed, namely:

- Contracting issues including lack of access to credit and loan facilities, work continuity, management capacity and business acumen, and poor availability and access to equipment.
- Consulting issues mainly because there are very few and very small consulting firms in Uganda; and
- Human resource development.

A number of strategies to address these issues have been proposed key among which is the establishment of the Engineering Council and the Construction Industry Development Board (CIDB). The proposed functions of these bodies are outlined later.

It is however argued in this paper that the issues such as identified in the Uganda government policy document and outlined above are intra-construction industry. They could be classified as micro- and mini-macro-issues. They probably provide the inertia or resistance to CID. In addition to addressing these issues one has to identify and address the driving-force issues to CID, i.e. the macro-issues, as well.

THE UGANDAN CONSTRUCTION INDUSTRY

The Ugandan construction industry is young and small but growing. The current level of growth rate is about 8%. Construction contributes 12% of GDP and employs about 5% of the population. The description of the size, structure and character of the construction industry can be presented by use of measurable indicators. Ofori (1998) argues that it is possible that the lack of progress in CID in many developing countries is due to the absence of measurable targets in programmes for improving the performance of the industry. Such indicators would help set targets, stimulate innovation while providing a basis for measurement and monitoring. He stresses further that indicators also help in the identification of deficiencies upon which remedial policies, strategies and actions should be based whilst providing a basis for benchmarking with others.

Ofori (1998) suggests the following as some of the indicators that may be used to measure and describe the construction industry, namely:

- Construction in the economy
- Level of implementation
- Volume of material inputs
- Level of imports into construction
- Corporate development
- Distribution of involvement
- Affordability
- Productivity

Apart from construction in the economy, all the other indicators relate to what is happening within the construction industry. These are examples of the indicators that I have termed micro or mini-macro, intra-industry indicators. Whereas the former measures output of the industry in terms of contribution to GDP, the latter relate to the efficiency of the construction industry, in its contribution to the development of the nation.

The Ugandan government, like in many other developing countries, has placed greater emphasis on the former than the latter. This situation probably stems from the fact that sponsors of development in the developing economies, i.e. World Bank (WB), International Monetary Fund (IMF) and other development partners have not demonstrated enough if any interest in the efficiency indicators above so long as the output indicators are "right".

Construction in the Ugandan Economy

The Ugandan economy has been a subject of praise by WB and IMF in the last ten years for the positive economic growth rate achieved over the period. This trend, they stress, is a result of good macro-economic policy. They could not be more right.

The construction industry has been a major contributor to the economic trends in Uganda in the 1990's. This period has been characterised by major infrastructure re-construction and maintenance projects, housing and industrial development. The following is a graphical description of construction in the Ugandan economy. The base data for the various graphs is attached in Appendix I. All values are at factor cost at 1991 prices (1 US$ = 724 USHS in 1991).

The figure below reveals that both GDP and construction output have not only registered positive growth but also doubled in absolute values during the period.

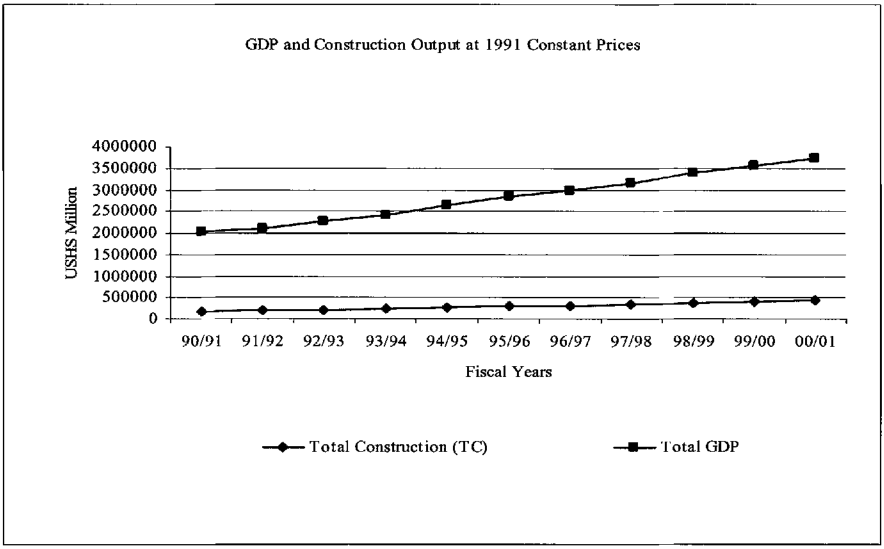

Figure 1 Variation of GDP and Construction Output

Figure 2 below shows that the contribution of construction to GDP is positively growing from below 10% in 1990/91 to about 12% in 2000/01 fiscal years respectively. The GDP and construction growth rates closely follow the same pattern. Although both growth rates have been greater than zero in the period considered, the construction growth rate has been always higher and sometimes twice as much. The pattern demonstrates the importance of construction in the economy. There are definitely other sectors with growth rates lower than that of GDP that are being compensated by that of construction.

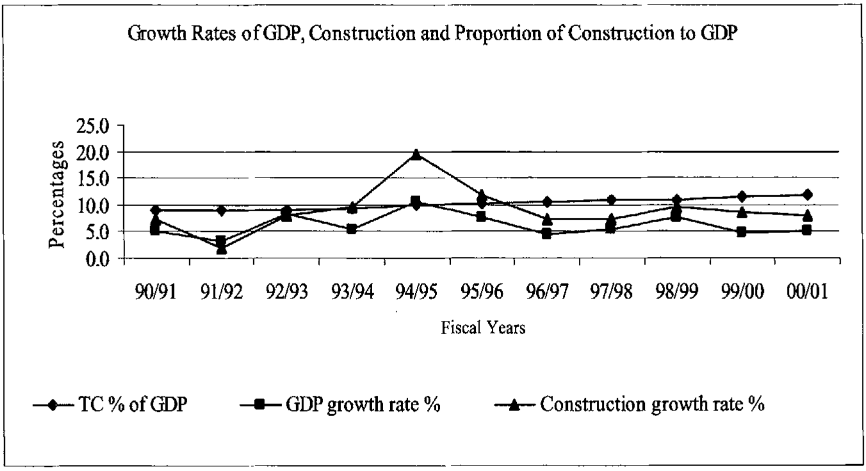

Figure 2 Construction Growth Rate, GDP Growth Rate and Proportion of Construction to GDP

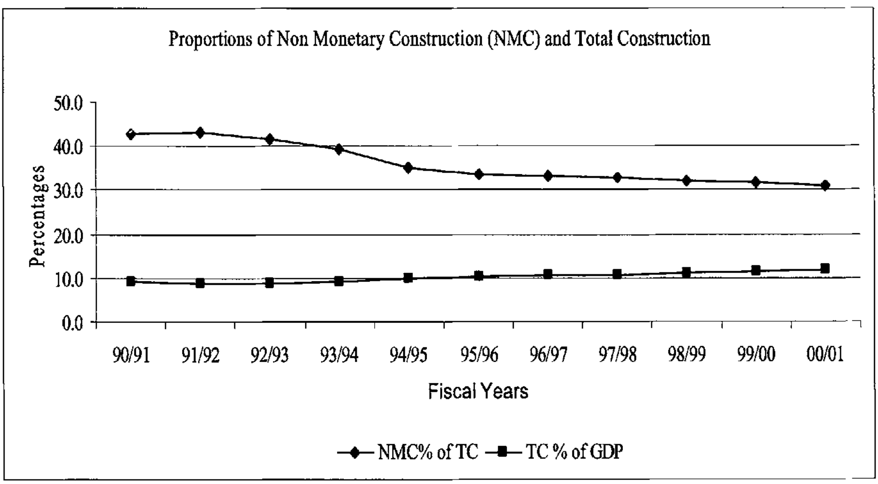

Figure 3 Proportion of Non Monetary Construction and Proportion of Construction to GDP

Figure 3 reveals that there is a substantial proportion of construction that is categorised as non-monetary comprising of owner-occupied dwellings and other self-built accommodation. This category forms the informal sector of construction in Uganda. The proportion has got a negative growth rate from about 43% in 1990/91 to about 31% in 2000/01 fiscal years respectively. The magnitude and trend may be explained by the fact that the Ugandan government has divested itself from provision and/or construction of housing, apart from one corporation that is still operational, on the one part, and the possibility of many small and sometimes labour only contractors being formed and registered to take advantage of the housing sector demand on the other part.

The Gross Fixed Capital Formation (GFCF) has been positively growing like GDP and construction output as shown in Figure 4.

Figure 5 shows that the contribution of GFCF to GDP is about 20% and generally not changing. Both construction contribution to GFCF and the contribution of the private sector to this proportion are almost the same and have positive growth from about 50% in 1989/90 to about 80% in 1998/99 fiscal years respectively.

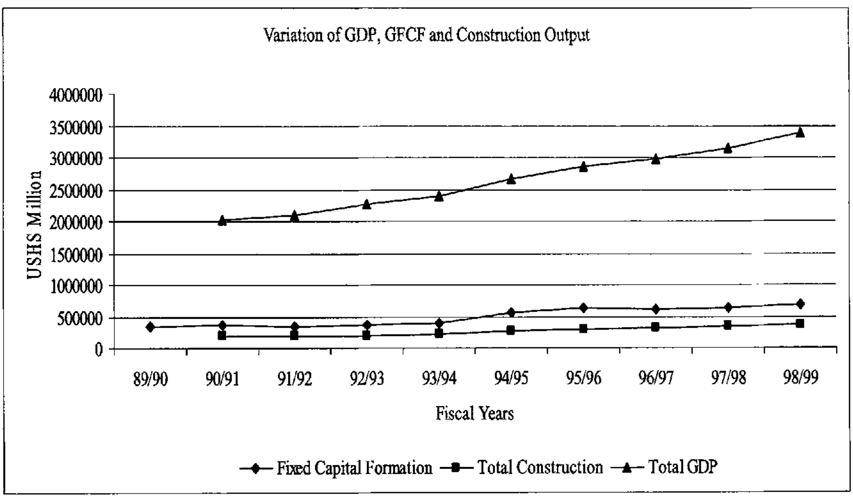

Figure 4 Variation of GDP, GFCF and Construction Output

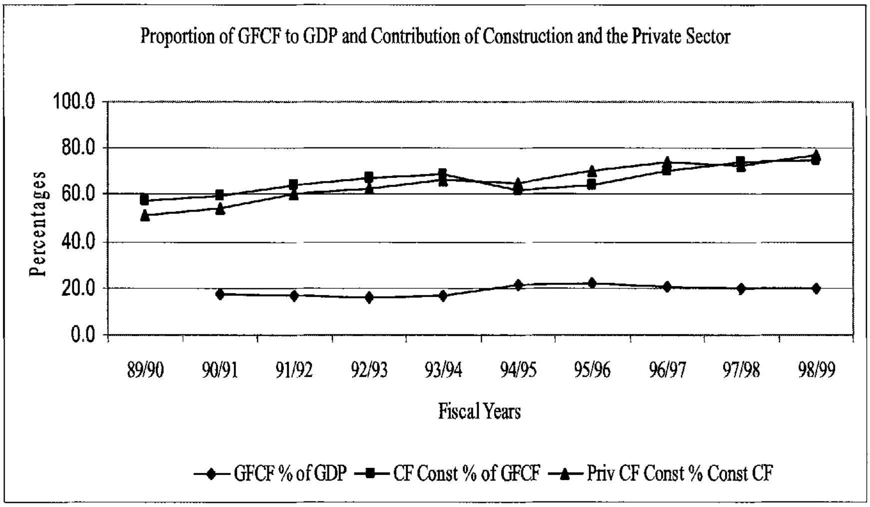

Figure 5 Proportion of GFCF to GDP, Construction Capital Formation to GFCF and Private Construction Capital Formation to Construction Capital Formation

Figure 6 below shows that the above proportions are similar and positively growing from about 45-50% in 1989/90 to about 70-75% in 1998/99 fiscal years respectively. The above relationship indicates that the private sector in Uganda's economy and also in the construction industry is providing most of the fixed capital formation.

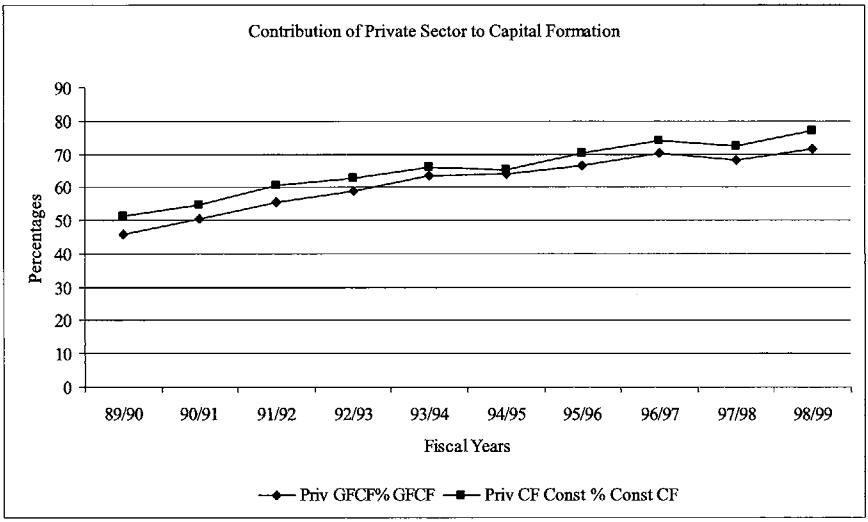

Figure 6 Proportion of Private Sector Contribution to Construction Capital Formation and GFCF

From the foregoing section, the construction industry in Uganda has been roughly and briefly described using two of the indicators that measure construction in the economy. The measure has not been exhausted because statistics related to employment and jobs created per industry sector are not existent.

Government does not probably consider other measures important maybe because her objectives as far as the construction industry is concerned are considered being met. It is however important to maintain a national construction industry database and a central agency administering CID to collect, process, and disseminate key construction data is of paramount necessity (Ofori, 1998).

CID IN UGANDA

The proposed policy, strategy and action plan for the development of LCI in Uganda has already been described in the background section above. It is however important to note that the proposed Engineering Council and CIDB shall have the following functions:

Functions of the Engineering Council

Government has proposed to establish the engineering council of Uganda that will primarily be responsible for setting standards for and regulating the basic education and professional training of engineers, technicians and artisans. The functions of the engineering council shall include, among others:

- Review and develop the syllabus for engineering training at technical colleges, polytechnics and universities.
- Set the necessary training programme for graduate technicians and engineers prior to registration.
- Conduct professional examinations.
- Accredit engineering training institutions.

Functions of the CIDB

Government has proposed the establishment of the CIDB to ensure effective co-ordination of all stakeholders in the construction industry and facilitate public and private sector dialogue on matters pertaining to the industry. The functions of the CIDB shall include:

Provide leadership and focus the support of the industry stakeholders for the development reform in the industry through:

- Review strategic issues critical to the development of an enabling environment.
- Advise on policy reforms necessary in the construction industry.
- Register and classify contractors and consultants.
- Work out modalities for accessing equipment and credit by local firms.
- Assess training needs and recommend training programmes.
- Monitor construction costs and suggest cost control measures.
- Provide a focal point for co-ordination, stimulation and promotion of research and development.

- Ensure exchange of information.

TOWARDS A THEORY FOR CID IN UGANDA

The above sections present a situation that is both haphazard and confused. The efforts of the Uganda government towards CID do not seem to have a theoretical basis. In fact the proposed bodies are left to define the theoretical and conceptual issues as part of their functions.

Many writers and scholars on CID (Ofori, 1998; Hillebrandt, 1999; Fox, 1999) have tried to define CID. Fox (1999) proposes a very interesting approach that follows a distinct school of thought that one can derive the theory from a set of data obtained in a multi-facetted study, i.e. 'the grounded theory approach'. It is probably not proper to try and argue against the approach by Fox mainly because of two reasons. Firstly, he presents credible evidence that other writers may have alluded to the same. Secondly, his study is still ongoing and it is only just that conclusions from the same are awaited.

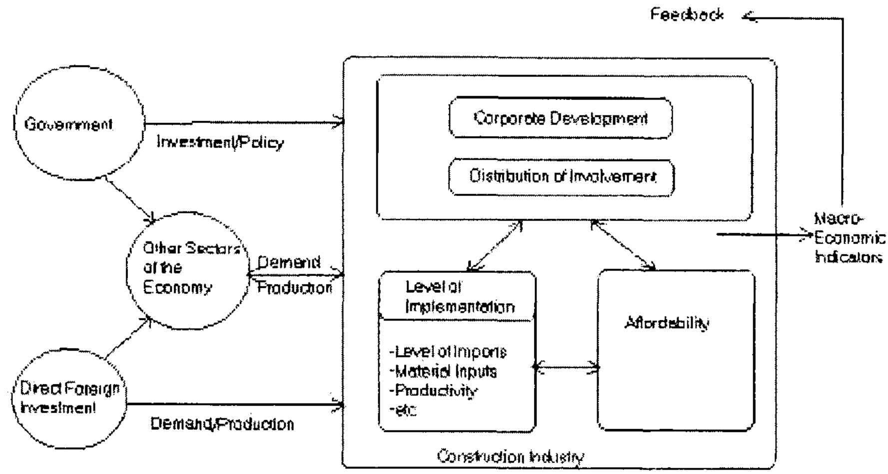

Figure 7 Conceptual Framework for CID Analysis

Moreover the initial assertion that the values and attitudes held by various stakeholders in any particular nation's construction industry are significant to either block of facilitate its development makes sense. However, an alternative approach seems possible and the following is an attempt to describe such.

The indicators suggested by Ofori (1998) may be categorised into macro-economic and intra-industry indicators as already suggested above. It has also been argued earlier that macro-economic indicators relate either to the drivers and/or originators of growth in the CID and measure the global output of the construction industry in relation to the economy as a whole. On the other hand the intra-industry indicators are either micro- or mini-macro-economic and relate to the efficiency of the industry to nurture and sustain development. They can also represent the inertia or resistance towards development in the industry. These indicators, therefore, describe the medium of change in the industry. Basing on this categorisation and utilising the principles of the systems theory, a conceptual model for the analysis of CID in a developing economy context for example Uganda, is suggested as shown in Figure 7 above.

The model describes the inputs and outputs into the construction industry in regard to CID. The model suggests that intervening or driving-force issues to CID include government policy, and investment, demand from other sectors of the economy and the stimulant to demand and production as a result of Foreign Direct Investment (FDI).

The output or macro-economic indicators measure the global performance of the construction industry and serve as input/feedback to government policy and investment decision in the construction industry and also as stimulant to FDI.

The construction industry has a continuous exchange with other sectors of the economy between demand and production. The level of demand by other sectors of the economy may also depend on their own intervening factors of government and FDI.

The construction industry is presented as an open system or a change process and medium whose internal level of development may facilitate or constrain the rate of response to the intervening factors and also the level and pattern of macro-economic indicators. It may also affect the level and impact of retention of FDI and hence re-investment in the industry. The methodology for data collection for the measurement of the intra-industry indicators is yet to be developed. This research effort will yield these useful baseline indicators for industry specific intervention-policies targeted to CID.

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APPENDIX I

GROSS CAPITAL FORMATION (MILLION SHILLINGS) 1991 CONSTANT PRICES										
Fiscal Year	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Gross Fixed Capital Formation (GFCF)	352,662	362,783	345,977	364,839	399,887	566,798	622,673	611,925	623,672	673,607
Private (Priv. GFCF)	162,311	182,693	192,619	214,285	253,685	362,518	413,132	428,842	425,765	480,801
Public	190,351	180,090	153,358	151,554	146,202	204,280	209,541	183,083	197,907	192,806
Construction (CF Const)	201,700	216,505	220,629	244,404	274,070	349,135	399,505	430,857	463,501	502,800
Private (Priv. CF Const)	103,587	118,067	133,885	152,941	181,298	227,113	280,368	318,572	334,788	386,857
Public	98,113	98,438	86,744	91,463	95,073	122,022	119,137	112,285	128,713	115,943
Machinery & Vehicles	150,962	146,278	125,349	120,436	125,818	217,663	223,168	181,068	160,171	170,807
Private	58,724	64,627	58,734	60,345	73,981	135,405	132,764	110,270	90,977	93,944
Public	92,237	81,652	66,614	60,091	51,837	82,258	90,404	70,798	69,194	76,863
Total Construction		183,130	186,531	201,271	220,604	263,519	294,727	316,676	340,207	373,377
Total GDP		2,032,023	2,094,673	2,270,271	2,392,859	2,646,954	2,852,756	2,982,180	3,143,090	3,386,643
GFCF % of GDP		17.9	16.5	16.1	16.7	21.4	21.8	20.5	19.8	19.9
CF Const % of GFCF	57.2	59.7	63.8	67.0	68.5	61.6	64.2	70.4	74.3	74.6
Priv CF Const % Const CF	51.4	54.5	60.7	62.6	66.2	65.1	70.2	73.9	72.2	76.9
Priv GFCP% GFCF	46.0	50.4	55.7	58.7	63.4	64.0	66.3	70.1	68.3	71.4

Source: (UBOS 1999)

GDP AT FACTOR COST AT CONSTANT PRICES (1991) Million Shillings											
Fiscal year	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01
Monetary Construction (MC)	104,941	106,052	117,888	133,823	171,405	196,137	211,147	228,100	253,339	277,120	301,491
MC % of GDP	5.2	5.1	5.2	5.6	6.5	6.9	7.1	7.3	7.5	7.8	8.1
Non Monetary Construction (NMC)	15,633	16,117	16,618	17,145	17,673	18,194	18,701	19,201	19,700	20,200	20,684
Owner Occupied Dwellings	62,556	64,362	66,765	69,636	74,441	80,396	86,828	92,906	100,338	108,366	115,414
Total Non Monetary	78,189	80,479	83,383	86,781	92,114	98,590	105,529	112,107	120,038	128,566	136,098
Total Construction (TC)	183,130	186,531	201,271	220,604	263,519	294,727	316,676	340,207	373,377	405,686	437,589
Total GDP	2,032,023	2,094,673	2,270,271	2,392,859	2,646,954	2,852,756	2,982,180	3,143,090	3,386,643	3,546,969	3,724,116
NMC% of TC	42.7	43.1	41.4	39.3	35.0	33.5	33.3	33.0	32.1	31.7	31.1
TC % of GDP	9.0	8.9	8.9	9.2	10.0	10.3	10.6	10.8	11.0	11.4	11.8
GDP growth rate %	5.2	3.1	8.4	5.4	10.6	7.8	4.5	5.4	7.7	4.7	5.0
Construction growth rate %	7.3	1.9	7.9	9.6	19.5	11.8	7.4	7.4	9.7	8.7	7.9

Source: (MOFPED, 2000; MOFPED, 2001)

MATERIAL WASTE IN THE CERAMIC TILING JOB

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ABSTRACT

Material waste is an important issue to be considered in order to improve building construction process and environmental sustainability of construction. Material waste can be as high as 20%, in terms of weight.

This paper presents the results of a very large research project, conducted by Universidade de São Paulo, together with 15 other Brazilian universities. Ceramic tiling was studied – among several other jobs – on several construction sites. Material waste was estimated and the causes for the waste were identified.

Ceramic tiles are very much used in Brazilian apartment construction in order to cover walls and floors. It is very common to have kitchens and bathrooms covered with these components.

This paper shows the tiles waste evaluation (it varied from 2 to 50%) and its causes. For example, the larger tiles, the greater the waste; the waste also increases when there is a great percentage of cut tiles.

INTRODUCTION

The construction industry professionals worried about material losses due to its double impact: environmental and financial. In terms of the environmental impact, waste occurrence means carelessness with natural resources, once the additional consumption is unnecessary and *leftovers* (apparent losses) harm nature at the moment of its deposition. Under the financial point of view, the industry inability to control its construction process and to reduce costs becomes evident when losses occur; this fact is very important when one considers the competitiveness in the sector.

Although the importance of the theme is unquestionable, few researches have been done in Brazil so far. PINTO [1] was the pioneer, in Brazil, in the waste studies; PICCHI [2] analyzed and estimated the financial losses on building sites; SOIBELMAN [3] studied several cases and accompanied the construction process during losses process quantification; SANTOS [4] was worried not only about quantifying the losses but also in finding ways to reduce them; and, recently, BOGADO [5] also studied this theme.

It is important to say that the studies here presented consider the losses under different concepts: either physical or financial; the case studies could involve only material or both material and labor. Besides, they could refer to the building site or to the overall construction process and the study could refer to only one or many cases. But all the researchers intended to get reliable Loss indexes and their causes. [6].

Studies about material losses started in the 60s, in The United Kingdom, by SKOYLES [7, 8] and SKOYLES & SKOYLES [9]. Their studies were the basis for research studies not only in Brazil, but also all over the world. For a long time this subject was forgotten in the international scenery, but the environmental question stresses the need to study material losses. So, some studies are being carried out, for example, in Hong Kong [10] and other countries [11].

In this context, the Civil Engineering Construction Department of Universidade of São Paulo (PCC-USP) has coordinated a national research that involved 15 other universities, aiming to obtain loss indexes of materials and components on building sites, identifying their causes and detecting / discussing alternatives for their reduction. The research was financially supported by FINEP – Financiadora de Estudos e Projetos do Ministério da Ciência e Tecnologia (Science Ministry Sponsor of Studies and Projects), and involved ITQC – Instituto Brasileiro de Tecnologia e Qualidade na Construção Civil (Brazilian Institute for Technology and Quality in Civil Construction).

This paper presents the loss indexes of ceramic tiles used in the ceramic covering services, obtained from the researches mentioned, following the proposed methodology for data collecting.

LOSSES AND WASTE CONCEPT

For this paper, losses are all material quantity exceeding the theoretically necessary material (TNM). The TNM is obtained from project data and/or defined by the engineer, and the real material quantity used (RMQ) is obtained from the bill/invoice. Mathematically, losses may be expressed as:

$$MLP = \left[\frac{RMQ - TNM}{TNM} \right] x100 \qquad (1)$$

where:

MLP	= material loss in percentage
RMQ	= real material quantity used
TNM	= theoretically necessary material

Material losses may be measured in different units (weight, volume, financial value). Regardless of the way it is taken into account, this paper considers that part of the material losses could be controlled in order to be reduced. But, under an economical feasibility evaluation, just a fraction of it is avoidable. This part is then called waste [3].

METHODOLOGY

Ceramic tiles losses on building sites

The flow chart of the processes (Figure 1) is used to identify when, where and how the material losses occur on building sites. It graphically represents the material steps on site, i.e., material acquisition, storage, production, use and transportation. The flow chart of the process is an important tool for loss analysis [12].

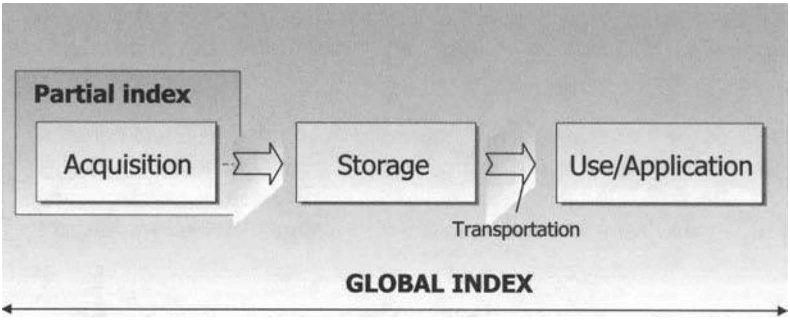

Figure 1 – Loss indexes example (ceramic tile job).

Losses, according to their nature, should be considered *incorporated*, when the final thickness of the covering is larger than the specified value; or it will be transformed into *leftovers*, when ceramic tiles are broken during application and/or transportation activities.

The losses of ceramic tiles may occur due to cuts for measurement adjustments. One may conclude that these losses are predominantly apparent (*leftovers*).

Ceramic tile loss measurement

When the loss index refers to more than a step of the flow chart of the processes, it is called *global index*; but when the index refers to a single step, it is called *partial index* [13]. In Figure 1, the classification is exemplified.

For the acquisition step, some examples of partial indexes are: "percentage differences between the paid quantity and the received one"; for the storage step: "rubbish generated during storage"; and, for the application step, the "percentage of cut tiles in relation to tiles that have not been cut".

While the partial indexes are used to detect where and how the losses occur, there is the possibility of acting directly on the job process. The aim of the global index is to make possible a job diagnostic related to material consumption. [14].

Data collecting

In order to achieve data standardization, for all the research steps, tables of contents were prepared and some objectives were formulated on data collecting, data-processing and analysis of the results.

Briefly, the methodology was intended to be developed in three steps delimited by two strategic dates related to on-building site: initial inspection (II) and final inspection (FI).

The first step of the methodology occurs previously to the II data and consists of data collecting planning. This step is related to a preliminary contact with the building site, to the collecting team training, to the involvement of workmen and company staff, and to the understanding and quantification of the services under study.

The second step consists of data collecting, which occurs between II and FI dates. The quantities of material that arrived and left the jobsite are measured and data concerning each step of the flow chart of the processes are collected. The partial losses indexes are then calculated.

After FI date, the third step takes place, with data-processing and analysis of the results.

In order to obtain the real material quantity used (RMQ) in the period, it is necessary to know the storage levels (STO) on both the II and FI dates. The difference between these quantities must be added to the quantity of material received (REC) at the site and were transferred (TRANSF) from other site to this site or from this site to other site.

To calculate the TNM one have: to quantify all the service accomplished in the period (SA); to define the theoretically material necessary to produce one unit of service (TNMUS); and to multiply these two values.

Application example for ceramic tiles service

In addition to the global index, some partial indexes were identified. In the acquisition step, it is mentioned: "percentage differences between the paid and the received quantity"; in the storage step: "rubbish generated during storage"; and, in the application step, the "percentage of cut tiles in relation to tiles that have not been cut".

Table 1 shows a simplified example for the calculation of global index of ceramic tiles with dimensions 20 cm x 20 cm (2 mm between two tiles) in a ceramic covering. The following formula is used:

$$MLP = \left[\frac{RMQ}{TNM} - 1\right] x100$$

$$MLP = \left[\frac{STO(II) + REC(II,FI) - STO(FI) \pm TRANSF(II,FI)}{SA(II,FI) x TNMUS} - 1\right] x100 \qquad (2)$$

where,

STO (II)	Quantity of ceramic tiles at II
REC (II)	Quantity of ceramic tiles at FI received between II and FI
TRANSF (II, FI)	Quantity of ceramic tiles at FI transferred between II and FI
STO (FI)	Quantity of ceramic tiles at FI
SA (II,FI)	Quantity of ceramic covering service accomplished between II and FI
TNMUS	theoretically material necessary to produce one unit of service

Partials indexes must be observed in order to explain the global index.

Table 1 – Example of ceramic tiles global index

RMQ		TNM		Global Index
Variable	Quant. (un)	Variable	Quant.	
STO (II)	5.000	*SA (II,FI)*	1.603,2 m^2	$MLP = \left[\frac{50.000}{40.000} - 1\right] x100 = 25\%$
REC (II, FI)	52.000	*TNMUS*	24,95 un/m^2	
STO (FI)	7.000	-	-	

1. To calculate TNMUS, a tile with $(20,1 \times 20,1)cm^2$ was considered, resulting from tile dimensions and the space between them.
2. The RMQ is obtained from equation 3.1 ($STO_{(II)} + REC_{(II,FI)} - STO_{(FI)}$).
   So, RMQ = 5,000 + 52,000 – 7,000 = 50,000
3. The TNM is obtained from equation 3.1 (TNMUS x $SA_{(II,\ FI)}$). So, TNM = 1616.2 x 24.75 = 40,000

Results and analysis

Table 2 shows the values of global indexes that represent the case studies by research project which were conducted by Universidade de São Paulo, together with other 15 Brazilian universities. The position measures (medians), dispersion measures (minimum and maximum values) and the sample size (n) are presented.

Table 2 – Sample statistics [15]

Job	Global indexes (%)			n
	Medians	**Minimum values**	**Maximum values**	
Floor	19	5	78	13
Wall	13	(1)	50	28
External Walls	13	5	19	3

One may note that the mere subdivision considering floor, wall and external walls is not sufficient for a better understanding of the losses detected.

Table 3 shows the distribution of cases considering the occurrence of cut tiles in the job. The authors believe that there is a relation between the losses and the percentage of cut tiles. One may observe that for floor covering job there are more cut tiles than for wall covering job.

Table 3 – Comparison of job: percentages of ceramic cut tiles [15]

% cut tiles	Floor		Wall		External Wall	
	Absolute	**(%)**	**Absolute**	**(%)**	**Absolute**	**(%)**
$C \leq 20$	2	15	11	34	3	100
$20 < C \leq 40$	7	54	16	50	-	-
$40 < C \leq 60$	4	31	5	16	-	-
Total	13	100	32	100	3	100

Table 4 shows the distribution of cases associating the size of the tiles with the losses. The evidence shows that big tiles generate more losses.

Table 4 – Comparison considering tile sizes [15]

Size of tile	Floor		Wall		External Wall	
	Absolute	(%)	Absolute	(%)	Absolute	(%)
≤ 20 x 20	7	54	23	72	3	100
> 20x20	6	46	9	28	-	0
Total	13	100	32	100	3	100

It is important to observe that floor covering job tiles are big sized. So, it is not possible to associate the losses of ceramic tiles only to the kind of job, if floor or wall.

Finally, Table 5 shows the media and median values of losses global indexes when both the percentage of cut tiles and tile sizes are considered.

There is a tendency to assume that bigger tiles have high loss indexes. Furthermore, independently of tile sizes, losses are greater when a high percentage of cut tiles occur.

Table 5 – Comparison between loss indexes: tile sizes and percentage of cut tiles [15]

(%)cut tiles	Size of tile	Floor		Wall		External Wall	
		Average	Median	Average	Median	Average	Median
C ≤ 20	≤ 20 x 20	5	5	13	8	12	13
	> 20x20	8	8	13	13	-	-
20 < C ≤ 40	≤ 20 x 20	17	18	14	14	-	-
	> 20x20	39	26	24	21	-	-
40 < C ≤ 60	≤ 20 x 20	18	18	13	13	-	-
	> 20x20	27	27	29	29	-	-

FINAL CONSIDERATIONS

The results that were obtained with this research show a great possibility to minimize the loss indexes in the ceramic covering services, once its values vary too much.

To reduce the consumption of material, companies must adopt more adequate cutting equipment, choose adequate places for material storage and, mainly, provide an efficient project coordination program in order to design rooms in a compatible way with the dimensions of existing tiles, because when tiles are cut, their *leftovers* will rarely be used.

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Global Competitiveness: A Case for Australia's

Building and Construction Industry

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SYNOPSIS

Australia's building and construction industry is relatively uncompetitive. The industry lags behind other sectors of the economy in articulating a globalisation policy framework and initiative that would maintain a regime of competitiveness. While the current government created necessary enabling environments to promote globalisation, the industry, compared with other sectors, appears not to have capitalised adequately on the opportunities to enhance its position. Although many reports have been advanced purporting to chart the way forward into globalisation, none has been rigorous and decisive enough to be taken seriously, let alone being sufficiently persuasive to industry associations and government. Hence, it is imperative that the key leveraging competitive angles are identified for the conception of a clear framework for industry policy and implementation.

The aim of this paper is to identify and present potential factors that would foster an enduring competitiveness regime for Australia's building and construction industry, charting directions for competitive industry policy and implementation. This aim builds, among other factors, on the notion that the potentialities of the information era have not been optimally explored and exploited by the local industry, despite the remoteness of Australia to the rest of the world. The relatively stable political atmosphere for over half a century, and the robust economy, human and natural capital, have either been ignored or squandered. It is envisaged that an articulation of a unique mix of the 'down-under' factors, will open up the door of opportunity to building and construction industry practitioners, associations and government, to better take advantage of the globalisation era, and strategically position themselves at the leading edge of the global market.

Keywords: *Building, construction, globalisation, down-under factors, competitiveness*

INTRODUCTION

Globalisation has become a buzzword, appearing in corporate annual reports as a bandwagon that must be joined; in government statements as a constraint to be faced; and in certain populist political circles as a threat to be resisted (Bryan and Rafferty, 1999). Although globalisation can mean different things to various people, it refers to the process of change which affects all sectors of the economy in all countries (Castles, 2001). It is the widening, deepening and speeding up of world-wide interconnectedness in all aspects of endeavour. Globalisation is about the combined, cumulative expression of trade, investment and finance on a global scale. It involves economic activity having to meet international competitive standards on the three Ps – price, productivity and profitability, as suggested by Bryan and

Rafferty (1999). For instance, Chinese wages, South Korean work practices, German technology and Japanese knowhow are the benchmarks by which economic activity in Australia is measured. The state is under pressure to facilitate local achievements on the three Ps.

Globalisation creates winners and losers. In this paper, a "transformationalist" view of globalisation is adopted (Castles, 2001). This viewpoint believes that new divisions will be formed both between the north and the south, and the east and the west. Australia, particularly its building and construction industry, must take a strong but measured stride for a share of the global market.

Globalisation opens up issues that conventional economics cannot explain. There is therefore a proclivity to ignore its complexity, or to assume that its impact can be regulated away. Since productivity in Australia is not at a global leadership level (PriceWaterhouseCoopers, 2001), competitiveness in many sector, including construction, is being pursued by making labour work harder for less return. Thus, labour is bearing the burden of national economic adjustment (Bryan and Rafferty, 1999).

Economic activity has always been global (Bryan and Rafferty, 1999). Nevertheless, the rate at which globalisation takes place in every facet means that the states' capacity to effect desired economic outcomes, is limited. Globalisation in the past two decades, particularly in the 1990s, has seen economic activity transcend national strategies. The only reliable way out is to move beyond the national agenda (Bryan and Rafferty, 1999). The bold steps already taken by few leading Australian building and construction firms such as Lend Lease, Peddle Thorpe, Multiplex and Woods Bagot into globalisation need articulation and a collective national appraisal.

Although many reports attempt to chart the way forward into globalisation, no model has been rigorous and decisive enough to be taken seriously, let alone being sufficiently persuasive to industry associations and government. Hence, it is imperative that the key leveraging competitive angles are identified for the conception of a clear framework for industry policy and implementation. Australia's building and construction industry lags well behind those in leading countries (PriceWaterhouseCoopers, 2001). While the government has created necessary enabling environments to promote globalisation, the industry, compared with other sectors, appears not to have taken up the opportunities to articulate a globalisation policy framework to enhance its position.

AIM AND OBJECTIVES

The aim of this paper is to identify and present potential factors that would foster an enduring competitiveness regime for Australia's building and construction industry, and chart directions for competitive industry policy and implementation.

While the works of Rashid (1990), Flanagan (1994) and Ofori (2000) make good references for this kind of study, only factors relevant to the Australian context are appropriate for close examination. Hawk (1991) highlighted ten themes for the building and construction industry to shift its tradition: changing customer ideas; creative reconsideration of traditional activities and finding new customers; adding value through integrated design and procurement activities; creating new approaches to organisational design and management to meet the challenges of dynamic local and international environments; focusing on diversity and a one-stop approach to service delivery; adapting industrial concepts of coherent continual improvement and adaptation; building a knowledge core through both integral and off-site research and development (R&D); experiencing limits in hierarchical structures by allowing variety to coexist with order; adopting emerging strengths of the Japanese organisation model of competition via integration rather than the American model of competition via fragmentation; and finally learning to learn.

After considering Hawk's (1991) ten themes against the state policy initiatives, the following Australian factors are deemed distinctive and worthy of further examination: information technology (IT) and the remoteness of Australia, political stability, and global integration in a robust economy.

The objectives of this study are to examine the extent to which these factors will facilitate the globalisation drive of Australia's building and construction industry, chart potential directions for global competitiveness of this industry, highlight necessary continuing R&D, and suggest how the proposals made can be applied in developing a more globally competitive Australian building and construction industry.

INFORMATION TECHNOLOGY ERA AND THE REMOTENESS OF AUSTRALIA

Australia's location affects its mode of trade. IT facilitates business transactions in a speed and manner unprecedented in history. The building and construction industry has many operators that have a high knowledge base, and deal with vast amounts of information. Nevertheless, the industry has yet to fully use IT to manage information and remove bottlenecks that retard productivity (Commonwealth of

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* Australia

Australia, 1999). The Commonwealth Government has released a preliminary statement of its policy approach to the information economy, as a basis for consultation with all stakeholders, with the aim of developing a comprehensive and inclusive national strategic framework (Commonwealth Government, 1998). This document articulates: a mission and a vision for Australia in the information economy; the values or guiding principles behind the strategic approach; the strategic priorities to bring about that vision; and key action areas to achieve the mission.

The information economy provides new ways of communicating. People can choose to participate at their own pace, at their own time, in a truly global economy. It is the end of the tyranny of distance for Australia. The building and construction industry must recognise Australia's comparative strengths in the information economy, as identified by the Information Policy Advisory Council (1997). First, Australia has well established legal and institutional structures that make it a safe and supportive environment for e-commerce. Second, it has a world-class telecommunications network and cable rollout, including a leading edge hybrid fibreoptic-coaxial cable network, providing a strong domestic market for online content and services. Third, its well-educated and highly skilled people have a tradition of rapid technology uptake, having one of the highest personal computer penetration rates in the world. Fourth, it trades strongly in Asia, and is equipped with the business and trade knowledge that is critical, as the information economy expands in Asia Pacific. Fifth, an Australian base allows for global continuity of workflows and efficient handover of activities, owing to differences in time zones. Sixth, it is an English-speaking country, with great multi-lingual diversity. Thus, it has the advantage as a regional base for firms. Finally, Australia's climate, way of life and environment are attractive to international enterprises. The building and construction industry must reorganise its supply chains to benefit from these strengths.

The growing trend towards telework or telecommuting in Australia (Ilozor *et al.*, 2001) is likely to make physical movement less relevant in future, and firms can hire workers who reside overseas and/or in remote locations. Australia already provides untimed local access to the internet; this will facilitate telecommuting. Electronic commerce provides opportunities to reduce costs within firms and across supply and distribution chains, and improves the quality of service to clients through faster response times. It reduces costs associated with inventories, procurement and distribution, and enables small and medium sized enterprises to better compete with larger firms.

AUSTRALIA'S POLITICAL STABILITY AND GLOBAL INTEGRATION

Australia has a stable democracy and the major political parties share a common commitment to business development (Hockey, 1999). A relatively resilient economy has been built on this stability. *Fortune* magazine, in its December 1999 issue, described Australia as the miracle economy which grew during the world financial crisis and slowdown. Australia is therefore the investment safe haven for the Asia Pacific region. Two points stand out as the reasons for this resilience. First, Australia's world-class regulatory arrangements, supported by the Wallis Inquiry and the corporate law reform package, provided the necessary security. Second, Australia's harmonious multi-cultural society has benefited from more than two centuries of immigration, such that one in twenty of its inhabitants is Asian-born, and more than 2.4 million of its citizens speak another language other than English (Hockey, 1999). Companies can draw on skilled managerial and technical staff who are fluent in regional tongues.

Although many economists argue that the state should deregulate cross-national resource flows (free trade, free capital mobility), there is no suggestion that the state should be absolved of all responsibility for overseeing these flows (Hawk, 1991; Bryan and Rafferty, 1999). Globalisation is not eradicating the role of nation state regulation, because (at a minimum) markets cannot operate in the absence of state supervision, and in the absence of a formally constituted global state. Hence, the stability of the nation and effective state regulation should be perceived by Australia's building and construction industry as potential enabling environments.

COMPETITIVENESS AGENDA IN AUSTRALIA'S NATIONAL POLICY

While comparative advantage is realised by free market, competitive advantage features the role of the state in helping or hindering the performance of individual firms. The role of the state here is twofold. The state should nurture productivity by supporting training and R&D. It should also move economic activity into ever-higher-productive operations, and facilitate the closure of low-productivity sectors and the opening up of high-technology sectors (Bryan and Rafferty, 1999).

The government's industry policy statement, *Investing for Growth* (Commonwealth of Australia, 1997), is less oriented to managing structural change than it is consistent with a competitive advantage perspective, but it shares an emphasis on the importance of state support for R&D and the advocacy of selective industry incentives.

Although its political leaders are trying to make Australia more competitive, economists generally suggest that only companies and not nations per se, can be competitive (Krugman, 1994; Porter, 1990). This underscores the need for Australia's building and construction industry to adapt to prevailing environments for competitive advantage.

An issue of particular relevance here is Australia's national policy focus on productivity. Generally, standard economic analysis rests on two propositions about productivity: that companies increase their competitiveness when they use their inputs more efficiently in the production of output; and that workers' wages cannot rise at a faster rate than they contribute to the value of production. It is assumed that productivity growth occurs when services are produced at lower costs. Yet productivity is understood as the key to competitive success in internationally exposed markets. Several key policy changes have been made at the national level in Australia to raise productivity in all sectors (including the building and construction industry). First, since the mid-1900s, there has been a shift from centralised determination of wages and working conditions to enterprise bargaining. This has permitted localised negotiation of productivity rises and resulted in a growth in individual contracts. Second, there is a growing emphasis on multi-skilling and workplace flexibility, resulting in both a variety of tasks performed by each worker and flexibility in terms of employment. The Evatt Foundation (1995) noted that in future, with few exceptions, the imperative for Australian workers will be to achieve international competitiveness and best practice. Third, the growth in casual work has permitted employment to respond directly to the level of economic activity. Finally, micro-economic reform and competition policy are often cited as spurs to improved productivity (Commonwealth of Australia, 1997; RBA Bulletin,1996; Hilmer, 1993), presumably because the free market adds the incentive to be more efficient and more mobile.

DIRECTIONS FOR GLOBAL COMPETITIVENESS

Many authors note that the level of competition in the international construction market is rising, with an increase in the number of international firms based in middle-income and developing countries (such as Brazil, China, Cyprus, Korea and Turkey) (see, for example, Oz, 2001). These firms' competitive advantages include access to inexpensive skilled personnel; close geographical, cultural and language proximity (Strassman and Wells, 1988; Rashid, 1990); and strategic use of IT (Commonwealth of Australia, 1999). Authors have analysed the sources of this competitiveness. Hasegawa (1988) considered the international strategies of Japanese construction firms and identified the following strategies they adopt: a transnational approach, new business development, operating as integrated engineering construction firms, exploiting opportunities for total project development, technology development, and exploiting financial strategies. Momaya and Selby (1998) compared the international competitiveness of the construction industries of Canada, Japan and the US on three fronts: competitive assets, processes and performance. As factors influencing competitiveness in global market have changed, there have been significant developments in the dominance of firms. The rise and decline of US firms has been extensively studied (Lyons *et al.*, 1993; Linder, 1994). Raftery *et al.* (1998) are among authors who have urged construction firms in emerging countries to acquire the expertise, resources and technologies to enhance their competitiveness.

Several authors have formulated strategies that firms must adopt for competitiveness in international construction in future. The Centre for Strategic Studies in Construction (1989) notes that successful organisations will be networks of specialist teams. Flanagan (1994) suggests that international contractors must focus on: speed in construction, innovation and delivery; flexibility in delivery mix; environmental consciousness; people development and deployment; automation and information; joint ventures, alliances and partnering; and financial engineering. The Market Analysis Task Force (1991) ranked the sources of future competitive advantage as: project finance; reduced project timescales; technical expertise, experience and reputation; willingness to carry risks; ability to procure globally; management and re-use of information; political backing; corporate infrastructure; ability to provide project funding; and ability to form partnerships or alliances with enterprises with skills in construction or other areas such as finance, design and operation.

CONCLUSION

As a growing number of firms in Australia globalise, the building and construction industry must also aspire to be competitive. The industry should be aware of this important new world order and how to benefit more from it. It must adapt and embrace it or risk being left behind in the old economy, with a small and declining share of the global market. As illustrated in this paper, globalisation and its implications for the industry should be understood and firms should continually change with time and technology. Globalisation should not be viewed from a holistic perspective by the industry in order for all the relevant issues to be identified and appropriately addressed. Further research is required to determine the best way forward, especially for the conception of definite frameworks for collective industry policy and implementation.

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GLOBALISATION AND CHANGES IN OWNERSHIP OF THE BUILDING AND CONSTRUCTION INDUSTRY

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ABSTRACT

Globalisation is profoundly affecting many industries, including the building and construction industry. The international restructuring of contractors, consultants and specialist subcontractors is a complex process, with only the largest firms in any country involved. Typically, globalisation is measured by the trade share in a country's GDP (exports and imports), and the level and extent of foreign direct investment (both inward and outward). In construction, the value of foreign work won by companies and the foreign share of company turnover have been followed and reported, and are often taken as the most appropriate measures of global activity in the industry. This paper takes a different approach, and investigates the extent and implications of changes in the ownership of major contractors, consultants and sub-contractors in both the international and Australian building and construction industries.

INTRODUCTION

Despite the importance of the issues associated with globalisation, defining globalisation is an issue in its own right. Guillen (2001) counted hundreds of citations using the term globalisation, with many versions of a definition. Common elements included global compression, interdependence, and integration. Also, there is a debate regarding over the significance of this phenomenon. Castells (1996: 92) argues we are living through a dramatic transformation into a global economy distinct from the "world" economy of the 16th century. Others argue the current process of globalisation is less dramatic than in the late 19th and early 20th centuries (Hirst & Thompson 1996). For some theorists, globalisation has altered the economic chances of significant populations (Rodrik 1997), while others argue that its effect has been exaggerated (Berger 1996; Krugman 1994).

Clearly, although globalisation is a major issue, it often generates more heat than light in the debate over its effects and implications. Friedman (1999) argues that there is a "golden straightjacket" that restricts countries to macroeconomic polices acceptable to the international financial markets, and that this impost on national sovereignty is a trade-off for faster growth from access to global capital. The main rules imposed by the "golden straightjacket" are: low inflation and price stability; balanced budgets; privatisation of government businesses and reduction of bureaucracy; and openness of markets in trade, capital and services.

The principle features of globalisation that Hatzichronoglou (1996: 13) identified are divided into general aspects and microeconomic aspects. These can be taken as a guide to the typical measures for globalisation. The main general aspects are:

- Competition in many markets between many new competitors from many countries
- Internationalisation of production and origin of products, services and capital
- International trade is increasingly intra-industry or intra-product in nature
- Diminished importance of trade, which is no longer the sole vector of globalisation
- Foreign direct investment (FDI) has become a crucial factor in the worldwide process of industrial restructuring and the development of global industries
- Financial sector is tightly entwined with the industrial sector.

Microeconomic or industry specific aspects of globalisation are:

- Global strategies adopted by firms and a global conception of markets
- Refocusing on core activities
- Priority given to external expansion and striving for critical mass
- Rapid increase in agreements and alliances and firms' networks

- Changes in internal organisation (e.g., the transition from fordism to toyotism).

Hatzichronoglou discusses two limitations on traditional ways of measuring competitiveness. Firstly, complexity can prevent clear research results when studying globalisation, and secondly, studies of globalisation have demonstrated the importance of means other than international trade for winning markets, notably direct investment. Such investment includes mergers and acquisitions (M&A) and takeovers. This paper looks at M&A in the construction industry over the past few years and the trend toward a small, global, "super league" of contractors who are seeking to widen their expertise, enter new markets and get closer to their international clients.

ISSUES IN GLOBALISATION OF CONSTRUCTION

There have been a number of recent papers looking at issues associated with the globalisation of construction. Raftery et al. (1998) reviewed recent developments in the construction industry in Japan and China and identified three trends: larger private sector participation in infrastructure projects, increasing vertical integration in the packaging of construction projects, and increased foreign participation in domestic construction. They attribute these trends to globalisation and deregulation of markets necessitated by fiscal, technological and managerial constraints and suggest the trends have enhanced the financial and technical advantages of industrial countries. .

Ofori (2000) considers issues raised by Raftery et al. and discusses the construction industry in developing countries, technology transfer and joint ventures, and the impact of policy reform on their industries. He criticises the focus on corporate development by Raftery et al., arguing that construction industry development should also consider development of: materials; project documentation and procedures; human resources; technology; contractors; and institutions, both public and private.

Crosthwaite (2000) examined the extent of international construction activity, basing the study on a cross-sectional analysis of published data of global construction spending and foundt that the role of construction changes as economic development proceeds. The share of construction spending in GDP first grows during less developed country (LDC) status, peaks during newly industrializing country (NIC) status and then declines as countries move from NIC to advanced industrialized country (AIC) status. The conclusion reached is that as economic development proceeds from NIC to AIC status, construction fails to maintain its share of GDP and declines in importance.

Low (1991a and b) argued that the function of marketing research in the context of international construction is to find out where the markets are in the world. Absolute measures (volume) and relative measures (growth) can be used for this purpose.

China is of particular interest to the global construction industry. Luo (2001) investigated Sino-foreign construction joint ventures, and the relationships between ownership, management control and joint venture performance. The study examines the management and performance of the joint ventures, and finds that dominant management control over joint ventures by Chinese partners is the major form of management with Sino-foreign construction joint ventures performing well. The economic growth in China has resulted in a strong demand for basic infrastructure, with road and power projects commanding top priority. The article by Wang et al. (2000a) is based on the findings from an international survey on risk management of BOT projects in developing countries, with emphasis on power projects in China. It discussed the criticality of foreign exchange and revenue risks, including exchange rate and convertibility risk, financial closing risk, dispatch constraint risk and tariff adjustment risk. The article also discusses measures for mitigating each of these risks. Wang et al. (2000b) analysed the unique risks associated the Laibin B concession (foreign exchange and revenue risks, which include exchange rate and convertibility risk, financial closing risk, dispatch constraint risk and tariff adjustment). Chan (1997) looked at how the combined mediation/arbitration process, unique to the People's Republic of China, works if the dispute is foreign-related, as defined under the Foreign Economic Contract Law. Foreign investment in the Chinese construction industry was analysed by Luo, Gale and He (2001). The types, structure and composition of partnerships in different construction joint ventures are described along with approval procedures, appropriate laws and regulations.

The opening of European borders in 1992 was seen an opportunity by some British contractors to expand into Europe. However, UK contractors such as McAlpine and Mowlem suffered heavy financial losses, while in Britain a severe recession weakened many contractors and led to divestment of unprofitable businesses, notably house building divisions. Continental European contractors such as HBG and Kvaerner became some of the UK's top contractors (Carrillo 1997: 1).

Crosthwaite (1998) studied international contracting activity performed by the top ten British construction companies, who account for approximately 90% of overseas activity by British firms. The research was concerned with the reasons, objectives and conditions considered important by these companies, and examined international performance of British construction firms 1990-96. The study analysed perceptions of the overseas market and the companies' objectives and future expectations with regard to overseas operations. The principal findings indicated that British firms had increased overseas activities during the study period. However, despite theory to the contrary and relatively high levels of construction demand in some developing countries, they had tended to conduct the major share of their overseas work in developed countries. . It was concluded that while market demand is a factor for overseas location by British construction companies, it is only one of many.

Alliances in international construction have become a focus in recent years. On alliances, Badger and Mulligan (1995) and Bing et al. (1999) address why alliances are formed, benefits of international alliances, types of alliances, trends in global construction, and risks encountered in international markets. Norwood and Mansfield (1999) look at how construction companies from developed and developing countries approach international joint ventures in the Asian construction market. Kangari and Sillars (1997) look at Japanese construction alliances.

THE TOP 20 INTERNATIONAL CONTRACTORS

There has been a growing trend toward increasing merger and acquisition activity in the industry. Many contractors' corporate strategies are based on an increase in size to allow them to become global players and take on larger building and infrastructure projects, such as Private Finance Initiative (PFI) projects in the UK, which require a strong balance sheet. The major players in global M&A are contractors from the US and Europe. Table 10.1 shows current ranking for construction contractors based on international revenues. Many of these companies have also been actively pursuing M&A strategies to expand their business and both enter new markets and increase their presence in global markets.

Table 10.1 International Contractors – Top 20

Rank	Country	Company	1999 Revenue US$ Int'l	Total
1	USA	Bechtel Group Inc	7,442	11,240
2	UK	Kvaerner PLC Group	6,540	8,420
3	Sweden	Skanska AB	5,984	8,232
4	France	Bouygues	5,007	11,462
5	USA	Kellog Brown & Root	4,721	6,399
6	USA	Fluor Corp.	4,669	8,707
7	Germany	Hochtief AG	4,402	7,833
8	UK	Bovis Lend Lease	4,113	5,341
9	France	Vinci, France	3,600	9,098
10	Netherlands	Hollandsche Beton Groep NV	3,407	4,428
11	France	Groupe GTM	3,162	7,591
12	Germany	Bilfinger + Berger	2,514.8	4,361.3
13	France	TECHNIP	2,503	2,607
14	USA	Foster Wheeler Corp.	2,240	2,884
15	Germany	Philipp Holzmann AG	2,100.6	4,254.3
16	UK	AMEC	1,958.8	4,452
17	Sweden	NCC	1,776	4,203
18	Japan	JGC Corp.	1,729	2,528
19	Korea	Hyundai Eng. and Const. Co.	1,633	4,299
20	China	China State Const. Eng. Corp.	1,545.3	4,878.6

Source: *Engineering News Record* <http://www.enr.com/dbase/2000tic.asp>

The top 20 international contractors come from nine countries. The two largest groups of four contractors are from France and the USA. Germany and the UK have three contractors each and Sweden has two. Completing the list are China, Korea, Japan and the Netherlands with one contractor each. There are only eight contractors with international revenues above US$4 billion. With the exception of Bouygues these firms get over 50% of their revenue from overseas. Some firms have over 70% of revenues from international operations.

MERGER AND ACQUISITION ACTIVITY

Table 10.2 details M&A deals done by global contractors between 1993 and 2001. What is significant is the increase in activity over the last few years. In 1999, 2000 and the first half of 2001 there were 12, 13 and 6 deals. By contrast, 1998 saw two and both 1996 and 1997 had five. After Bechtel, the largest contractors are French. In 2000, the French construction group Vinci, through its merger with GTM, became the world leader when it replaced Bouygues, which appears to be more interested in developing its broadcasting and telecommunications activities (Michaud 2001).

The 2000 edition of Construction Europe's *European Contractors Survey* showed that Bouygues and the SGE Group of France were Europe's biggest two companies. The GTM Group was third, while Sweden's Skanska rose two places to fourth and AMEC of the UK jumped three places to seventh (after takeovers). HBG of the Netherlands slipped two places to tenth, Eiffage of France was eighth and Germany's Philipp Holzmann dropped from third to sixth. The two other German companies in the top ten retained the places they held in 1999, with Hochtief ranked fifth and Bilfinger + Berger ninth.[1] The merging of Walter Bau and Heilit-Woerner Bau in 2000 made Walter Bau Germany's fourth largest construction group.[2]

Germany's big three contractors prospered in the construction boom after reunification in the early 1990s. But with a slump in the domestic market after 1998, Hochtief AG, Philipp Holzmann AG and Bilfinger + Berger Bau AG all went for American acquisitions. Hochtief and Holzmann owe much of their overseas revenue growth to acquisition, while Bilfinger + Berger has grown most of its international business organically (Reina 2000). Owning the Turner Corp. raised International work to 75% of Hochtief's 2000 revenue. Philipp Holzmann's U.S. operations, primarilly J.A. Jones Inc, helped drive its international revenue to 60% of the total (Reina 2001).

The extent of corporate activity by contractors can be illustrated by looking at the recent M&A efforts of three particularly active firms from three European countries: Hochtief, AMEC and Skanska.

Hochtief

Hochtief has an established worldwide presence either via its subsidiaries or, as in Australia, South Africa and the Netherlands, through major associated companies [3]. Hochtief's M&A strategy is driven by a quest for more international business, both to keep up with key global customers and to improve its risk profile. By having a presence in markets around the globe Hochtief can smooth peaks and troughs in regional market cycles. Hochtief reinforced its position in Southeast Asia by raising its interest in Australian contractor Leighton Holdings Ltd. from under 50% to a 51% controlling share. Through Hong Kong-based Leighton Asia Ltd., the firm has grown its regional business, notably in Malaysia. Hochtief has also been buying in Canada, the Czech Republic and Poland. For Hochtief and

[1] <http://www.construction-europe.com/cgi-bin/frontend.cgi?showlink~construction~magazine~150~~> (6/7/01)
[2] <http://www.walter-bau.de/englisch/html/press_release_15.htm> (6/7/01)
[3] <http://www.hochtief.com/hochtief/englisch/html/index_a_e.htm> (6/7/01) Press release 20/9/99

Holzmann, North America has emerged as a key market at a time when construction demand at home remains weak (Reina 2000).

In 1999, Hochtief acquired the Czech construction company Vodni Stavby Bohemia (VSB), Prague. Hochtief has moved systematically into selected growth markets in Central and Eastern Europe. In Poland, it is successfully represented by Hochtief Polska Sp and now with the acquisition of VSB, it is initiating a lasting presence in the Czech construction market.[4]

In 1999, the acquisition of The Turner Corporation, of Dallas, Texas was the largest acquisition in Hochtief's history. Hochtief's growth strategy for North America also included the acquisition of 49.99% of newly merged Canadian construction companies, Armbro Enterprises Inc. and BFC Construction Corporation.[5]

[4] <http://www.hochtief.com/hochtief/englisch/html/index_a_e.htm> (6/7/01) Press release 8/11/99

[5] <http://www.hochtief.com/hochtief/englisch/html/index_a_e.htm> (6/7/01) Press release 4/5/00

Table 10.2 Mergers and Acquisitions in the International Construction Industry

Date	Acquirer	Target Company
2001	Balfour Beatty	ABC-NACO (Rail Systems Div)
2001	Bovis Lend Lease	IRW
2001	Taylor Woodrow	Bryant
2001	Alfred McAlpine	Kennedy
2001	IMES	Kvaerner sold Davy Weighting Systems
2001	Hochtief	Leighton Holdings
2000	Skanska	Kvaerner
2000	Kvaerner	Whessoe International
2000	AMEC	Ogden Environmental & Energy Services
2000	Conflex Stena Offshore	Kvaerner sold RJ Brown
2000	Finning International	Hewden Stuart
2000	Bovis Lend Lease	Project Consultants
2000	Bouygues	Colas
2000	Walter Bau	Heilit-Woerner Bau
2000	Skanska	Exbud
2000	Balfour Beatty	Marta Track Constructors Inc
2000	Balfour Beatty	Metroplex Corporation
2000	Vinci Group (SGE)	GTM Group
2000	AMEC	AGRA Inc
2000	Skanska	IPS
1999	Centex	AMEC sold Fairclough Homes
1999	Union Electric Steel	Kvaerner sold its UK metals manufacturing
1999	Lend Lease	P&O sold Bovis
1999	Bovis	Tanvec
1999	Bovis	WR Adams (US health facilities)
1999	Bovis	Crystal Group
1999	Hanson	Olin Jones Sand
1999	Hanson	Brewer
1999	Hewden Stuart	Enmore Plant Services
1999	Hochtief	VSB
1999	Hochtief	Turner Corp
1999	Bouygues	Kvaerner France
1999	Skanska	Karl Steiner Holding
1998	Hanson	McAlpine US aggregates and engineering
1998	Colas	Hanson sold its US road building business
1997	AMEC	Babcock International's process division
1997	AMEC	BKW Eagleton
1997	Jacob's Holdings	Ropner (shipping, property)
1997	Jacob's Holdings	Tiptoes (car transport)
1997	AMEC	SPIE SA

1996	Hollandsche Beton Groep	Higgs & Hill (construction division)
1996	Hewden Stuart	Kvaerner sold Agent Plant
1996	Kvaerner	Trafalgar House
1996	AMEC	Spie Batignolles
1996	AMEC	S/W Infrastucture Maintenance
1995	Walter Bau	Concrete Constructions
1993	Bilfinger + Berger	Baulderstone Hornibrook

Sources: <http://www.ukbusinesspark.co.uk/bpmerg.htm>; On-line database ABI/INFORM Global (Proquest) which includes *International Construction*; *ENR*; *Access Czech Republic Business Bulletin*; *Northern Echo*; *AFX News*; and individual company web pages.

AMEC

In 2000, AMEC strengthened the strategic partnership with SPIE. Also, in another example of a European construction firm moving into America, AMEC acquired Toronto-based design firm AGRA Inc. Acquiring AGRA increased AMEC's access to North American markets and boosted its design capacity. In 1999, AGRA itself had made seven acquisitions, including the purchase, for $20.5 million, of Vancouver-based H.A. Simons, an engineering and service company (ENR, 2000a: 15). The combined group will have design service revenues estimated at $1.14 billion, and the merger puts AMEC/AGRA into the top five engineering design firms, behind Bechtel and Fluor Daniel (PF, 2000: 4).

Skanska

In 1999, Skanska purchased 70% of Swiss construction group, Karl Steiner Holding AG, Zurich, the deal giving Skanska an interest in New York-based Turner Steiner International Inc. a construction management company that operates in the Mideast, Southeast Asia and Europe (ENR, 1999a: 21). In 2000, Skanska Europe acquired 66.1% of the Czech Republic's largest construction company, IPS and completed its acquisition of a 75% controlling stake in Exbud, a leading contractor in Poland.[6]

In 2000, Skanska also acquired the construction division of Kvaerner, the company's fifth European acquisition giving Skanska a strong presence in the U.K., Hong Kong and India. For Kvaerner, selling its core construction business will leave it focusing on oil, gas and industrial work (ENR, 2000c: 9). Kvaerner Construction is among the U.K.'s top five construction companies, and represents "the conventional face of contracting." Until now, Skanska had a "tiny toehold" in

[6] <http://www.whitecase.com/pr_skanska_exbud_poland.html> (6/7/01)

the U.K. through its 1997 acquisition of 7.6% of troubled contractor Costain Group Ltd. (ENR, 2000b: 14).

AUSTRALIAN CONTRACTORS

The ongoing strength of the Australian economy and growing expenditure in building and engineering construction during the 1990s made the industry an attractive investment opportunity to overseas contractors. Further, Australia is seen as a base from which to expand into the Asian market, with a number of Australian companies active across the region.

Australian construction contractors have therefore been prey rather than predator in the global M&A round. The exception is Lend Lease Corp (LLC). The acquisition of UK's Bovis Group was a £285 million (A$718 million) buyout, funded though cash reserves and debt (AFR 1999). Acquiring the world's largest construction management contractor put LLC into a leading position in European and U.S. construction markets. Buying Bovis extended capabilities globally, giving Lend Lease Projects new opportunities and markets, especially in the Americas and Europe (ENR, 1999b: 13). The deal targeted a multiplier effect, with LLC's development, investment and project management arms able to create opportunities for each other. The deal did not impact LLC negotiations to acquire other businesses, including Boston Financial and parts of Amresco in the US.

Table 10.3 Takeovers of Australian Contractors

Date	Acquirer	Company	Acquirer's Country	
1993	Bilfinger + Berger	Baulderstone Hornibrook	German	Private
1995	Walter Bau	Concrete Constructions	German	Private
2000	Lend Lease Corporation	Bovis Group plc	Australian	£285M
2000	Development Land DBS	Australand	Singapore	
2001	Hochtief	Leighton Holdings	German	51%

Sources: Annual reports, Australian Financial Review.

The experience of other Australian firms is rather different. The takeover of Baulderstone Hornibrook by Bilfinger + Berger (B+B) put three directors from B+B on the nine-member board. At the time of the takeover the managing director of Baulderstone estimated turnover in 1996 would be about 12% of total B+B turnover (AFR 1996).

The Walter Bau (WB) takeover of Concrete Constructions (now Walter Construction) put four WB directors on the board and a finance director who is a permanent resident in Australia. A new banking facility included $200 million for syndicated debt, provided through Deutsche Bank and Bayerische Landesbank, enabling Walter easier acccss to Asian projects (AFR 1996)..

Leighton Holdings and Hochtief have had a long history together. Hochtief maintained a share of between 40% and 49.9% since early 1980's although it was reduced to 45% in 1996. Hochtief has 3 directors on Leighton's board, one resident in Australia, and the relationship extends to financial support if necessary. In February 2001 Hochtief moved to majority control with 51.5%, and can consolidate balance sheets. In turn, Leighton Holdings acquired John Holland at end of 2000,adding to existing subsidiaries Theiss and Leighton Contractors.

Walker Corporation was taken over in 2000 by Australand Holdings. The Chairmans Report stated the significance of the acquisition of the Walker Corporation Group, which had been finalised in mid January 2000 when management control passed to Australand. During 2000, the benefits of operating synergies, savings in overheads and reduced financing costs emerged. Other key aims had been to identify and acquire new development sites to replace existing projects and underpin organic growth, and to maintain, if not improve, margins on projects already under construction. In 2000, Australand was in turn acquired by the Singaporean company Development Land, a joint venture formed by a recent merger of DBS Land and Pidemco Land and ultimately owned by the major bank DBS and the Singaporean Government.

CONCLUSION

The construction industry has become more global, deregulated, open and competitive as a result of changes in the international economic system. However, because construction is not a commodity that can be traded across borders and the industry is not suitable for internationally integrated production, the effects of globalisation are seen in the rise of international contracting and corporate activity. On the one hand, the construction industry is like many other industries in having to adjust to a challenging new and dynamic business environment. On the other hand, the role of FDI in construction is not very important when compared to other industries, where investment in production, storage or distribution facilities is a major part of the global strategy. By contrast, in construction there are many mergers, acquisitions and strategic alliances taking place, so portfolio investment is important.

This review of recent M&A activity in the global construction industry has revealed a significant increase in M&A activity since 1996. The most active firms have been European contractors, who are rapidly expanding into the American and Asian markets, while US contractors have not been as active. This is probably a reflection of the different states of their respective home markets. The efforts of the European contractors to get into the US market have seen a number of takeovers there with the express intention of gaining access to a market that was seen as growing and offering new opportunities. In contrast the European markets, particularly in Germany, have been constrained.

Although alliances and joint ventures in international construction have become a topic for research in recent years, there have been few papers on M&A in international construction. However, M&A is becoming an increasingly important aspect of the industry as firms seek entry into new markets and the industry consolidates around a small number of very large global contractors. Increasingly, growth of contractors, particularly from Europe, is driven by increases in turnover due to acquisitions.

The Australian construction industry has been of particular interest to German contractors, with three of the largest making acquisitions in the last few years. The motivation for these moves has been a combination of diversification and a search for growth markets, both in Australia and the region. It is too early to comment on the success or otherwise of these moves for the parent companies.

Finally, it is becoming clear that the strategic intent of the largest international contractors is to pursue size (in terms of revenue) and geographical diversification. For these firms the decision on which markets to enter, North or South Asia, Western or Eastern Europe, North or South America and so on, is possibly the most important facing their managers. Differences between the characteristics and prospects of the construction market in developing and industrial countries will determine the success or otherwise of these moves into international markets. The long-run growth and position of their companies could, to a large extent, depend on the outcome of this choice.

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Theme 4:
E-Commerce & the Construction Process

The Development of e-Commerce within the Global Construction Industry

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INTRODUCTION

By the end of the 1980's most disciplines within the field of construction had software available to assist professionals in the carrying out of complex calculations. During the 1990's the use of e-mail as a communication device was developed. The World Wide Web, which was also established in the early 1990's, was developed during the decade, both as a communication device and as a source of knowledge.

The late 1990's saw a boom in speculative investment in 'dotcom' companies. At the time the ICT-revolution was being hyped as having potentially the same impact on society and business as had the early 19th century Industrial Revolution. The dotcom bubble burst in mid-2000 and since then development in ICT has been carried out at a staider pace.

In America productivity seems to have increased following massive investment in information and communication technology (ICT) over the years, but the increase has only been noted recently. The annual average increase was 2,9% since the end of 1995, twice the rate of the previous two decades, while in Japan and Europe productivity has failed to pick up. (The Economist 2001, p. 21).

Prof. Martin Fieldstein of Harvard University (Fieldstein 2001) has postulated that the growth of the US economy during the 1990's has been primarily caused by increased productivity due to the adoption of ICT by that country's commercial and industrial companies.

Companies in commerce and industry in general are currently using ICT to enable them to become more efficient and to reduce operating costs. Some of the uses ICT is being put to include business-to-business (B2B) and business-to-consumer (B2C) applications as well as enterprise resource management (ERM). A number of web-enabled management systems have been developed to assist professional managers to handle projects. There is a view that the next big step in industry productivity will be achieved by the use of web-based project management systems; the success of these will depend on the development of broad-band networks which will be capable of transporting large volumes of information quickly.

E-commerce can be described as the carrying out of business using electronic means and it has been expanding over recent years as the use of the Internet has increased.

The two main areas of e-commerce are business to consumer (B2C) where manufacturers and service providers sell their products to consumers via the Internet, and business to business (B2B) where suppliers and subcontractors on the supply chain of large manufacturers are managed via the Internet.

The international construction industry, although possessing characteristics different from those of other industries, is following the trend of adapting its business methods to the new electronic ways of doing business.

In the following, a brief review of the development of e-commerce will be followed by an overview of the two types of this commerce which have evolved. A brief review of seven case studies of the development of e-commerce in non-construction related companies will illustrate trends which the international construction industry can be expected to follow, as well as giving an indication of the costs and savings involved in developing e-commerce.

Finally, developments in e-commerce within the international construction industry will be described and consequences and risks discussed.

THE EVOLUTION OF E-COMMERCE

In January 2001 Bill Gates forecast that during that year more than 400 million people worldwide would surf the web's 4 billion pages and spend 500 billion dollars on goods and services in the process (Gates 2001). This statement refers to B2C and it can be presumed that as the use of the Internet develops so will this type of commerce.

Table 1 shows the global distribution of Internet-users in February 2000 when the global total was estimated to be 275 million.

Table 1: Global distribution of Internet-users

Area	Population (million)*	Internet users (million)	Internet –users percentage of population
Canada and USA	300,862	136,06	45,2
Europe	810,000	71,99	8,9
Asia/Pacific/Middle East	3.534,000	56,19	1,6
South America	336,000	8,79	2,6
South Africa	39,357	1,20	3,0
Rest of Africa	709,643	1,26	0,2

Source: E-Commerce p.8 *The Economist Diary 2001 (mid-1998 figures)

Fig 1 shows the evolution of Internet users worldwide according to two different sources.

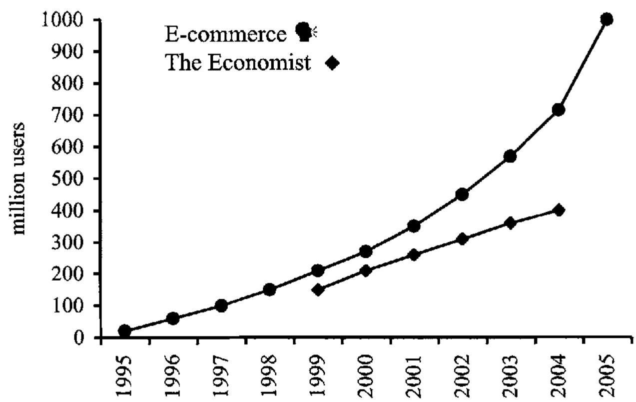

Figure 1 Internet users
Sources: E-Commerce, p 8 The World in 2001, The Economist p 110

Internet business in 1996 amounted to about US \$ 2 billion. In 2003, B2B e-commerce is expected to reach between US \$ 3 and 7 trillion and B2C is expected to reach between US\$ 150 and 500 billion, according to the source consulted (Bothma 2000).

BUSINESS TO CUSTOMER (B2C)

Many web-based e-commerce initiatives have already become normal in the daily life of individuals and companies. These initiatives include on-line banking, insurance, purchase of consumer goods such as books, sale and rental of property, distance education, air-line booking, hotel and tour reservations, to mention a few.

Tentative initiatives have been launched involving legal consultation and arbitration. Some law societies have reacted to these alleging the risk of client-attorney confidence being breached. The recent launching of on-line banking in South Africa has been a welcome first step in breaking a monopoly held by a handful of traditional banks and is expected to reduce banking costs and improve services. Two low-cost airlines based in the UK sell tickets only on the Internet.

The overall benefits that have been gained by the introduction of the above type of e- commerce are: speed of response; economy of effort (the client carries out all operations on his computer and does not need to visit shops, banks etc.); reduction in costs (the intermediary is eliminated); broadening of product choice; the ability to read proper product specifications and to not have to rely on store sales-staff.

BUSINESS TO BUSINESS (B2B)

Business to business activities usually consist of large manufacturing organisations streamlining their supply-chains by the use of electronic means. A recent development is the grouping of businesses to obtain economies of scale by group procuring and purchasing.

E-COMMERCE CASE-STUDIES

During May and June 2001 The Economist published a series of case studies on the successful use of e-commerce in business and industry. These will be summarised here as they illustrate well the implications of e-commerce on world business. The trends described can also be considered to be indicative of possible developments in the construction industry.

The General Electric case study illustrates the volume of buying and selling that can be achieved electronically by one company; the Seven-Eleven study indicates the investment involved in installing ICT systems; the Siemens study again illustrates the investment needed for an international conglomerate to transform itself into an electronically-enabled company; the Merrill Lynch experience deal with knowledge management and asset management; the Cemex study illustrates how an international construction-related company achieved increased efficiency and profits using e-commerce; the Valeo study shows how a car-component manufacturer has rationalised its electronic procurement system. Finally the Enron study indicates the sheer volume of information that can be managed electronically. While the above companies cannot, with one exception, be considered to be construction-related, all carry out processes which are also followed by the international construction industry: Integration via knowledge management; procurement and sales. It is believed that developments in the international construction industry will follow the trends illustrated above, as discussed in the next section.

General Electric is the largest company in the world and it currently buys and sells more through its private on-line market places, US$ 20 billion in 2001, than all the independent B2B market places put together.

All of GE's big divisions run their own web market-places, both for internal and external use. They use three initiatives: e-buy, e-sell and e-make. Advantages of using B2B technology have been the cost savings and improved product quality.

Seven-Eleven is a convenience store operator and is today the biggest retailer in Japan. It was set up in 1973 and in 1995 undertook a major overhaul of its information-technology systems. It wanted all of the companies in its supply chain to use one common system.

The system had to serve 6 000 stores scattered across Japan – there are now more than 8 500, and the number is increasing.

The overhaul took three years to complete, cost US$ 490m and involved installing software in 61 000 computers in stores, the company's head office and vendor firms. The firm calculates that it has over the past ten years saved about US$ 2,5 million a year by becoming a paperless business.

Siemens is a sprawling conglomerate with more than a dozen business units. It operates in 190 countries and employs 470 000 people.

The company is currently spending US$ 860 million in an attempt to turn itself into an e-conglomerate. This involves, as well as investment in technology, organisational change – changing the company's mindset.

There are four elements to the e-investment plan: knowledge management, on-line purchasing, customer contact and administrative tasks.

Costs are expected to be cut by 2% in the short term and by 3 to 5% in the medium term.

Merrill Lynch is America's largest stock-broking firm. In 1998 the company started overhauling its e-commerce procedures for dealing with Merrill's vast primary business of providing information, trading and underwriting services to institutional clients. Another branch of the company's business is the management of US$ 550 billion worth of assets. The company's primary business however, is creating, distributing and using information.

Cemex is a Mexican cement producer. It first introduced the use of information technology in its operations in the late 1980's.

The company is currently installing computers with Internet access into employees' homes.

Fifty-five percent of Cemex's holdings are outside Mexico and it has used information technology to integrate new acquisitions into the group.

The company has established, with four other companies, an ICT consultancy as well as Construmix, a construction industry on-line market place and Latinexus, an e-procurement site.

The company aims to complete its "e-enabling" process by making the company's operations web-based, with all its employees having access to their own files, the company's data and outside information through a single personalised portal. Corporate finance is already run this way and procurement, sales, distribution, and supplier and customer relations are also intended to become as Internet-based as possible. The company expects that by going on-line it can save some US$ 120m, presumably per year.

Valeo is one of the world's top manufacturers of car components. The group has some 180 production-sites around the world and more than 100 separate operating divisions.

The company only started implementing e-business systems in mid 1999 and has recently begun a shift from being intra-net based and internally focussed to being web-based and looking out to its customers.

Valeo's most important e-commerce initiative is a project called e-procurement@supplier-integration. This was started in April 2000 and is aimed at four main areas: web-catalogues, e-negotiation, purchase-knowledge management and supplier-relationship management.

Enron was the world's biggest energy-trading business. At the end of 1999 it launched Enron-online, its internet-based trading platform. It had a daily volume of trades of 5000 with a notional value of US$ 3 billion. Enron Products offered 1,5 m different products online, and Enron's revenues grew from US$ 7,6 billion in

1986 to US$ 101 billion in 2000. Traded physical volumes had only grown by 30% annually in previous years and the surge to 60% in 2000 is attributed to the introduction of EnronOnline.

The implementation cost has been US$ 20 million in back-office costs.

THE INTERNATIONAL CONSTRUCTION INDUSTRY

Not many decades ago the construction industry was characterised by fairly rigid demarcation between client, consulting engineer (or architect) and contractor: the engineer designed, the contractor constructed and the engineer supervised construction.

Over the last 20 years the boundaries of responsibilities have been eroded; contractors started the erosion by carrying out design-construct and turnkey contracts and then got involved in financing when BOT projects were launched. Currently some contractors are participating in partnering exercises with their clients and are taking on facilities management. This means that there is a tendency for a new breed of contractors to assume responsibility as construction managers for the whole construction process, from inception through design, construction and operation to eventual demolition. Some contractors in the power sector, for example, assume ownership, temporarily or permanently, of the facility they design and build.

The consequence of the above is that there have emerged a number of extremely large international contractors that are knowledge-driven and able to carry out EPC or lifetime projects. As in other areas of industry such as the petroleum, aerospace and car industries, the size of these companies and their multi-national activities provide them with the ability to exploit the advantages of e-commerce, some of which are described in the following where, for the sake of simplicity, it will be assumed that the owner, designer and contractor are separate entities.

E-COMMERCE AND THE INTERNATIONAL CONSTRUCTION INDUSTRY

Hamilton (2000) has reviewed the development of e-commerce in the construction industry. He draws a distinction between e-commerce (domestic or consumer trading) and e-business (business transactions) and states that: "While CAD drawing files have been transmitted electronically for over 10 years, only 10% of bills of quantities are exchanged electronically. A survey carried out in March 2000 in the UK of the supply side of the construction industry showed that the use of e-commerce accounted for no more than 5% of the transactions. Within five years it is expected that 50% of the transactions will be carried out using e-commerce."

A further trend is the setting up of on-line business-to-business exchanges or "portals" which serve the construction industry. It is expected that each type of industry will have its specialised portals and that only three portals will succeed in any one industry.

e-Government

Government is quite often a key client for many members of the construction industry. There is a tendency for governments to transact business electronically, which will undoubtedly facilitate the life of consultants and contractors. The UK is pushing for e-government and in a recent study the South African government indicated its willingness to follow the same route (Franz, 2001). Areas of government being considered for the ICT treatment include public safety, taxation, healthcare, motor vehicles, home affairs (home office), education and business services, social services and digital democracy (via access to legislation etc). It may shortly be possible to actually vote electronically. The importance of the government as a client is seen when it is realised that the South African government buys goods and services to the value of R 65 billion (US$ 7,8 billion) a year.

In the USA, there is a move to carry out permitting electronically (Dewberry, 2000).

Procurement by the owner

An example of the use of information and communication technology (ICT) by owners, or to be more precise, owner-funders is the use of the Internet by the World Bank and other funding agencies to advise the international construction industry of tendering opportunities for consultants, providers of goods and services and contractors. The WB's communication vehicle, Development Business, informs industry of the progress of funding negotiations with client countries so contractors and others can be made aware at an early stage of up-coming projects.

The tendering process itself is handled by government departments, many of which use e-mail for transmission of tender documents, or make them available on specific web-sites.

In this way there is a worldwide two-way flow of information. Contractors can inform themselves of WB-funded projects anywhere in the world; countries receiving WB funding can be assured of receiving tenders from contractors around the world.

It is not impossible that a similar process will be used in the near future by large multi-national contractors for the procurement of goods and services.

Design

The design industry can avail itself of the above procurement systems; it can buy or rent appropriate software from web-based suppliers; it is possible that they will also be able to rent very sophisticated software for 3D designs on the Internet; a number of larger companies have already developed in-house systems which, in some cases, encompass 4D capabilities (i.e. 3D over time).

The benefits of e-commerce, as explained above, are more easily exploited by the large multinational designers (which are often construction-managers too) as they pursue 24 x 7 production: the Internet allows them to transfer drawing-files from their office in the US at 19:00h to a subcontractor in, say, India where it is 04:00h of the next day, so that they can be worked on during the US night and returned in the US morning. E-commerce procurement systems will allow the designers to procure sub-contractors throughout the world, wherever there are competent, inexpensive professionals. E-commerce will also enable multi-national designers to procure local partners in targeted countries. These partners will provide necessary local design information and will eliminate the need for international travel by expensive US or European professionals.

Contracting

It is by the contractor that many of the advantages of e-commerce can be obtained. As explained above, modern contractors are tending to develop their businesses as knowledge-based entities, hiving off assets such as construction equipment to subsidiary plant hire companies. This means that the contractors need to have core management skills in-house and need to be able to procure personnel, materials, equipment and finance worldwide.

The Swedish based www.eu-supply.com claims that construction industry buyers are making savings of 15% by buying materials, products and services through its site. There are claimed to be 100 live transactions going on at any time with an average value of £100 000 (US$ 140 000). The company also claims to work with half of Europe's top 30 contractors, including at least 12 of the UK's top 30. (Internet, 2001).

Personnel

There are a number of web-based personnel agencies which link job-seekers with employers seeking, usually contract, employees. Many consulting and design companies maintain an in-house data-base of selected professionals as the personnel agencies often tend to be "job-shops". For key personnel, companies still tend to engage head-hunters who work on a personal-contact basis.

An example of an electronic personnel agency is ExecutiveJobFinder, (www.executivejobfinder.com) which claims to serve the world's top executives in 39 countries.

Materials

Using web-based procurement systems, materials can be procured anywhere in the world that produces them to a required standard: the spread of the ISO system helps to guarantee international standards. Reinforcing steel, cement, formwork and structural steelwork can be procured from countries such as China at competitive prices. This topic has also been examined elsewhere (Murray and Zagaretos, 2002)

In South Africa eSteel Alliance has been established to provide a platform for buyers and sellers of steel to trade on the Internet (Lace, 2001).

Equipment

By now all major equipment manufacturers have web-sites from which potential purchasers of plant and equipment can source items.

Many plant-hire companies also have web-sites and the availability of equipment can be quickly checked by e-mail.

Auctions of used plant equipment can be carried out on-line. A cut-throat novelty is for potential purchasers of equipment (and materials) to carry out a reverse auction where sellers bid against each other by dropping prices. According to ENR, 2001, the US equipment industry generates equipment sales of US$ 25 billion a year. The number of transactions being carried out by e-auction is estimated to be less than 1% and while traditional auctions of used equipment account for only 10%, this figure is expected to be eventually pushed up by the growth of on-line auctions.

Sub-contractors

Again, sub-contractors can be identified by Internet-searches as many have web sites. After the establishment of a minimum level of quality, reverse auctions can be conducted as for used equipment.

CONSEQUENCES

The consequences of the growth of e-commerce are expected to be reduction in costs, increased speed in carrying out transactions, the increase of purchasing leverage, as large companies already associate on portals to obtain economics of scale and, finally, the globalisation of procurement. This will probably lead to a further shift in manufacturing and service activities being carried out in developing countries where labour is less expensive than in the US and Europe.

RISKS

Risks faced by users of any ICT system start with hacking (Rippenaar, 2001). South African organisations are said to face a 5% chance of falling victim to cyber criminals.

Further worries include the "Five P's" of the Internet: policing, pornography, privacy, protection and property (Hindle, 2001). There are also fears of the monopolistic tendencies of the industry. Another concern of those trading electronically in developing countries concerns the reliability of servers and networks. Finally, there is the potential difficulty of enforcing contracts internationally when global procurement has been employed.

CONCLUSIONS

An attempt has been made to establish trends for the development of e-commerce in the construction industry by examining case studies of seven companies representing traditional industries and commerce.

There is a definite trend for e-commerce to develop in the construction industry, perhaps more slowly than expected as companies come to grips with and address risk issues.

It is recommended that further research be carried out in the following areas:

- the influence of e-commerce in encouraging the formation of mega-construction companies (as has happened in the car, aviation, energy and defence industries).
- the benefits of e-commerce to the construction industry.
- how small and medium enterprises can participate in e-commerce (and whether they are).

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E-construction in the USA: A new research agenda

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ASTRACT

This paper reviews the market trends of Internet based information technologies in the US construction industry. Current technologies focus on three major functionality areas: collaboration for the design stage, project management and procurement of construction supplies. With their adoption, firms expect benefits in terms of lower transaction costs, shorter lead times, and increased value added to clients. Since 1997 significant investment have been made on the providers of these services. Consolidations, gaps among provided services and customers' expectations and resistance by some industry sectors are some of the factors that have created market uncertainties and much debate about possible future growth and directions. Having reviewed the characteristics of these technologies, the authors propose three analytical frameworks to study the possible impacts of these technologies on construction market and management of firms. These frameworks are: Transaction Cost Analysis, in which transaction costs are used to explain particular governance structures of production; Network Perspective or Network Theory in which the success and performance of individual firms depend on resources controlled by and interaction of firms; and Resources Based Management in which firms are viewed as bundles of heterogeneous resources and the ability of firms to add value to products is the focus of analysis. Application examples of the frameworks to the construction industry operations are provided.

INTRODUCTION

The construction industry is characterized by information-intensive operations. Efficient information processing (data access, communication, storage and control) is complicated by the extreme fragmentation of the industry demand and supply sides. In the late Nineties, web-based technologies raised great expectations about improved business performance and cost reduction. More recently the demise of many dot.com firms in the USA has cooled down these expectations and created uncertainties about the future of electronic supported construction. Much uncertainty is due to an unclear understanding of how market characteristics, value chain and business operation systems affect web related business functions and how these functions affect business paradigms. This paper presents three different theoretical perspectives for researching such a phenomenon. These frameworks are: Transaction Cost Analysis, in which transaction costs are used to explain particular governance structures of production; Network Perspective or Network Theory in which the success and performance of individual firms depend on resources controlled and developed through the interaction of firms; and Resources Based Management, in which firms are viewed as bundles of heterogeneous resources and the ability of firms to add value to products is the focus of analysis.

An overview of information technology (IT) development in the USA and a description of the various capabilities and applications of web-based technologies to the construction industry precede the discussion of these theories.

IT EVOLUTION IN THE CONSTRUCTION INDUSTRY

The first IT use in construction was the application of mainframe automated accounting systems in very large firms. The same technology was applied in the Sixties to structural engineering solutions. The next leap forward was the 1968 introduction of EDI (Electronic Data Interchange), conceived to process an extensive volume of structured data through mainframe computers and proprietary communication systems called value added networks (VAN). Typical applications required all participants to trade through their network using technically rigid and complex standards. Typical VAN functionalities included purchasing, pricing, inventory status, invoicing and shipping, and receiving. The systems were efficient but too expensive for their adoption by small and medium sized firms. In the Eighties personal computers and new software developments began to improve the efficiency of some project activities, such as planning, design, project management and site management. Client/server systems, consisting of interconnected local area networks (LAN), were developed. These systems and new software were developed as separate applications along a project's various functional phases and professional specializations. The results have been the increased operational efficiency of individual firms, but also the creation of islands of automation, with little impact on the performance of the construction industry at large. The ability to transfer project documents and data throughout participants has been inhibited by lack of standards, e.g., file formats. This problem has prompted the pursuit of software interoperability. The last phase of IT growth coincided with the global development of the Internet in 1991 and the introduction of the World Wide Web browser technology in 1994. In a construction project the Internet is used to improve communication and data sharing among geographically dispersed participants.

Within a project extranet system and using a web browser, users conduct a variety of collaborative activities that are supported by capabilities such as real-time conferencing, project e-mail and message board and discussion. In addition to these benefits, the Internet can create virtual networks of buyers and sellers of supplies. In this regard, electronic commerce consists of two distinct business and consumer components: Business-to-Consumer transactions (B2C) and Business-to-Business transactions (B2B). Unlike the B2C markets where buyers share the same value from the web host, both sides of B2B participants derive benefits from aggregating a large number of buyers and sellers, i.e., market liquidity. Marketing, evaluating and search costs decrease as transacting parties spend less effort in searching each other, often eliminating expensive intermediaries. The larger the number of parties who use these information networks, the more valuable the latter become because of the exponential growth of possible business opportunities. The advent of these networks, therefore, appears to change business paradigms and competition among firms whose focus on internal efficiency must be complemented by emphasis on external resources and affiliations.

WEB BASED TECHNOLOGIES

Web-based technologies focus on three broad and overlapping functionality areas: collaboration for the design phase, project management and procurement of construction supplies. The first two functionalities focus on project flow, the last one on product flow services. Initially marketed separately, these applications have been progressively integrated into a single service, following mergers and consolidation in the application service providers (ASP) market. Additional web-based services include auctions and product directories and information services, as shown in Table 1.

Collaboration for design and engineering activities.

Most applications are supported by advanced modeling software based on industry standard DWG file format. Often offered by CAD vendors, these applications provide a centralized repository of project

Table 1 Web-based services for the construction industries

Directory services	Product directories with basic information about suppliers and manufactures and links to their websites
Auction services	Auctions, sales, liquidations of commodity type products, e.g., steel, and used equipment
Project	On-line tools for communication, document sharing, control and

management services	repository, and software applications for managing construction projects
Collaborative design services	Central repository for a wide variety of graphic media, including CAD files, that can be accessed, reviewed and modified by project participants and on-line communication tools
Procurement services	B2B marketplaces that facilitate the full on-line procurement process of supplies and offer on-line catalogues
Information services	Market analysis and forecasts, construction cost data, bids and RFP deadlines, project news and marketing services

drawings, allow simultaneous access and ensure that all design participants are working with the most recent drawing version. Most software packages have capabilities redlining (individual modification and comments can be recorded and univocally identified in the same drawing file), drawing version control and creation of complete design history, in addition to solid modeling and automatic development of construction details, schedules and cost analyses. These applications enhance the coordination of design documents and their consistency through on-line collaborative review and threaded discussion among geographically dispersed design participants. New software applications, in addition, allow rapid prototyping and feasibility analysis with faster development of design solutions.

Project management

Project management involves the generation, communication and control of a significant amount of documents among project participants. Timely coordination, approvals and interaction are prerequisites for project success. Web-base project management systems consequently focus on capabilities that enhance workflow and work process management. The first set of capabilities encompasses meeting minutes, correspondence management, requests for information (RFIs), transmittals, submittals, approvals and change notification. Work process management capabilities include estimating/budgeting, scheduling, job progress reporting, multiple job reporting and accounting. By allowing a non- stop flow of messages for coordinating, logging and updating project data, these technologies reduce time consuming and costly paperwork and related distribution efforts. Electronic communication, in addition, shrinks processing time cycles, e.g., approvals of shop drawings and RFIs.

Procurement of construction supplies

These applications generally encompass three types of services to the procurement process of clients and general contractors: on-line catalogues for construction products (with prices and distributor inventory availability); on line bidding that consists of invitation to bid (ITB) and request for quotations (RFQ) and may also include sales/auctions of surplus materials and used equipment; and exchanges with the simultaneous presence of "bid" and "ask" quotations from multiple parties for commodity products, such as steel. The potential market for these services is significantly larger than that of collaborative design and project management web-based technologies. Manufacturing inputs are, in fact, approximately one third of all US construction inputs. With on line bidding, the purchasing work flow is supported by capabilities such as identification of local sources of supply, analysis of purchase history, importing bill of materials into RFQs, attaching drawings to specified items, bid comparison, automated issuance of purchase orders, and shipment status tracking, among others. These capabilities, if fully implemented, lead to transaction cost processing savings. Electronic commerce offers buyers the advantages of market liquidity with wider selections, reduced prices and fewer information asymmetries. Advantages of suppliers (manufactures, distributors and retailers) include increased sales from access to a large pool of buyers, lower marketing efforts and better inventory management.

Fragmentation of demand and supply, low profit margin and fierce competition are some of the characteristics of the construction market that favor the penetration and growth of web-based technologies. Electronic market places offer aggregating benefits. Low profit margins create the need for efficiency within firms by reducing operational costs through web-based project management or collaborative design applications. These technologies, at the same time, allow firms to reduce the completion time of their services and offer value-added services through electronic networking. In the long run the above-described web based technologies offer several potential benefits to construction firms and industry. The regular gathering of buyers and sellers in a common network leads to a more transparent market with fewer information gaps and price discrepancies. A second benefit encompasses lower transaction costs. Network effects decrease search and marketing costs, while one-stop-shopping and standard processes streamline project management efforts. Project extranets, in addition, facilitate collaborative efforts that in turn create more value to clients, at least in terms of reduced project time, design document inconsistencies and possible litigation.

The above-summarized benefits are not a reality yet, because of the slow adoption of these technologies in the industry. Most design and construction firms still rely on in-house servers rather than ASPs, thus perpetuating fragmentation. The adoption of project extranets is a slow process that does not match the time horizon of investors, as the demise of many ASPs for lack of financing shows. Networking benefits, in addition, are significantly reduced by the lack of participation of subcontractors, a very important element of the construction industry's value chain. Today there is no clear understanding of how electronic networks and transactions impact construction business processes and how changes in these processes influence the development of web based technologies. Theoretical frameworks are needed to define and possibly measure their impact.

The following notes discuss three possible theories that are useful in examining these issues (Skjoette-Larsen, 1999).

TRANSACTION COST ANALYSIS

The first efforts for exploring the governance structure of a firm's supply chain can be traced in the establishment of institutional economics (Coase, 1937). This theory and its successive developments (Williamson, 1975) explain why a firm exists, through the use of transaction costs. According to Williamson firms use different governances of economic exchanges, depending on the nature of the transaction itself and four environmental and behavioral factors: bounded rationality, uncertainty/complexity, opportunism and small numbers. Table 2 shows the typical transaction costs of purchasing a construction product, from a buyer viewpoint.

Table 2 Transaction costs of construction product procurement

Type of transaction costs	Activities
Search costs	Gathering information about possible sellers and issuing RFQs.
Negotiation costs	Contacts, RFIs and negotiation.
Decision costs	Multicriteria decision making about purchasing options.
Administration costs	Placing/receiving an order, shipping instructions, checking order status and verifying delivery and managing accounts payable.
Control costs	Coping with possible contractual non-performance or default

When applied to the construction realm, the theory has been an effective tool in explaining the governance structures of interfirm relationships, particularly in the case of homebuilders (Eccles, 1981) and commercial contractors (Costantino et al., 2001), but less useful in providing a measuring tool for identifying and assessing the transaction costs of a given interfirm business relationship. The development of a detailed taxonomy of transaction costs along the different operations of a construction firm would be the first step in identifying and eventually quantifying costs and benefits in the adoption of web-based technologies by firms. A preliminary attempt in this direction can be seen in Figure 1, which shows the possible benefits from subscribing to electronic procurement services for construction supplies from a B2B marketplace. The figure, drawn from the business plan of a startup company in 1999 (Eisenmann, 2000), illustrates the main steps of the procurement process by a construction firm, including the possible resale of unused supplies and surplus equipment. The figure does not show the inevitable learning and operational costs that are incurred by a subscribing firm.

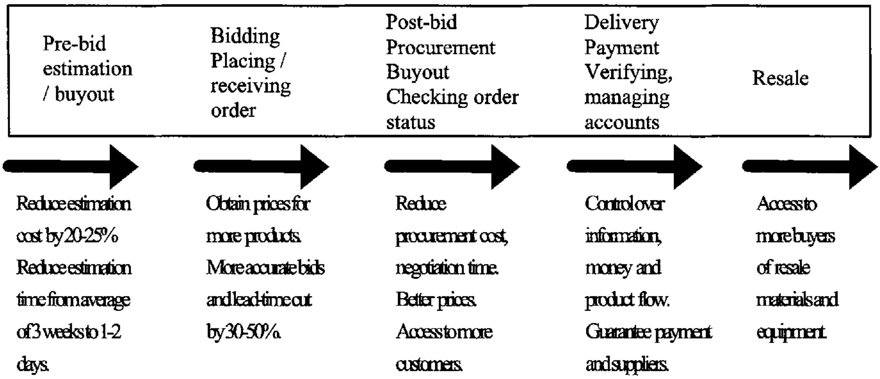

Figure1 Possible savings through electronic procurement

Most construction marketplaces are offered and operated by third parties (on paper, with neutral behavior towards both buyers and sellers). There may be the case of those owned by buyers, as in the case of the car industry. The AECventure, jointly owned by Skanska (Sweden/US), Amec (UK/Canada), Bovis Lend Lease (Australia/UK/US) and Hochtief/Turner (Germany/US) is an example. With a combined sales of approximately $30 billion, this venture aims at an increased bargaining position with suppliers and cross-border trade and, at the same time, lower costs to clients, among others. Table 3 compares the marketplaces operated by third parties and buyers respectively, in terms of the extent of potential transaction costs savings. We assume that a buyer's marketplace cntails relatively higher investment costs and is less effective in decreasing search costs vis-a-vis a third party marketplace (on paper, the latter allows buyers to negotiate with a larger set of suppliers), but at the same time it can be more easily integrated into a firm's existing procedures and protocols.

Table 3 Potential savings from third-party marketplace and buyer's marketplace

Transaction costs	**Third party marketplace**	**Buyer's marketplace**
Search cost	++++	++
Negotiation costs	+	+++
Decision costs	+	++
Administration costs		++
Control costs		++

NETWORK THEORY

While the transaction cost approach focuses mainly on economic issues, the network theory pays attention to the relationship between transacting parties (Ouchi, 1980). Long-term cooperation, sharing of common goals, openness and trust are some of the factors for the success of networking parties that, through interaction, benefit from each other's resources and, through mutual adjustment, create more value in the network output. Cooperation and interaction build upon a focus on how a firm structures internal resources and relates its own activities to other firms' activities and resources in a network. This approach entails a corporate shift away from a focus on only internal resources and activities. Over the years this form of production organization (in between market and hierarchies as described by Williamson) has been growing in the industry, initially in the car sector in Japan and garment sector in Italy. In the construction industry the attention to the benefits of long-term collaboration is not new. Almost twenty years ago, an Italian scholar proposed the design of the "macrofirm", a network of small and specialized firms around a large contracting firm with coordination and planning functions of the entire network (Dioguardi, 1983). Similarly, empirical studies showed the existence of the "quasifirm" in the business relationship of contractors and subcontractors in the US homebuilding industry (Eccles, 1981).

The use of "rich" information within a network is another important characteristic that matters in assessing the impact of Web-based technologies. Typical descriptors of information "richness" are bandwidth, interactivity, customization and, often, security. Information richness is defined as the ability to change understanding within a time interval. According to Daft and Lengel (1986), "communication transactions that can overcome different frames of reference or clarify ambiguous issues to change understanding in a timely manner are considered rich." The possible equivocality or ambiguity of transmitted information can be overcome by using rich media, such as face-to-face communication or group meetings, and, in the case of networks, by sharing common goals and trust, and building upon long-term relationships. Rich information, however, has a limited "reach" because it is accessible only to the network's parties and it is not available to outsiders, a very large segment of market population. Web-based technologies, on paper, eliminate the trade-off between "reach" and "richness", by allowing greater reach and, at the same time, the exchange of rich information. Before the growth of the Web, large construction companies that wanted to connect offices were limited to leasing private telephone lines. Single ownership offered information privacy and security. With the availability of the Internet, these companies are shifting to VPNs (Virtual Private Networks) to connect job sites by using data encryption to maintain security.

These private networks have the advantage of using existing in-house IT applications and avoid the training and development costs that are incurred in joining the public networks managed by ASPs. In this regard, network theory is useful in identifying the barriers to the market penetration of the public networks that are offered by ASPs. Notwithstanding their promised advantages, the former have not grown significantly since their initial introduction a few years ago. It should be noted that long-term relationships, trust and security of the pre-Web networks were developed over a long time period and repetitive collaborative projects. These results cannot be easily replicated in the short term in public networks where inter-firm and web-based collaboration may be mandated by clients and is often limited to a single project.

RESOURCE-BASED VIEW

The resource-based theory builds upon the view of a firm as a bundle of heterogeneous resources and capabilities (Penrose, 1959). According to this theory, sustainable competitive advantage is based on the maximization of a firm's resources and capabilities, as they are applied to a value chain. Competitive advantage is sustainable when the former are considered valuable, scarce and difficult to replicate by competitors (Skjotte-Larsen, 1999). A firm's core competence (or strategic assets) is the central focus of the resource-based approach. The consideration of core competence, therefore, can lead a firm toward several distinct or combined goals, e.g., the enhancement of its specialization and know-how, outsourcing of resources that are not relevant to its core operations and/or targeting new market areas in which to deploy its strategic assets with success. This pattern can be seen in the US construction industry, particularly in the last ten years. Design/build (sometimes including financing) services by contractors, design services by subcontractors and facility management services by designers are some examples of firms that, building on their own traditional strengths, enter new markets. The availability of Web-based technologies has spurred much discussion of their slow adoption by construction firms, notwithstanding their potential benefits. Buyers address problems such as training and development costs for small sized firms, changes of internal processes and protocols and the need for interoperability of software applications. Sellers point to the perpetuation of old business processes and resistance to new approaches. To date, no consensus about future developments has emerged. If these issues were considered from the resource-based viewpoint, the following probable questions would be asked: Is the implementation of these technologies at a firm's core competence? How can these technologies be used to enhance a firm's strength? Can any of a firm's activities and systems be outsourced, so as to shift existing resources to core business operations? These questions seem to have been addressed already by the manufacturing and service sectors, which are generally ahead of the construction industry in terms of innovative approaches. The most advanced applications of the resource-based view is found in Enterprise Resource Planning (ERP) approach, an integrated system of different IT applications that is used by large manufacturing and service firms. The ERP system supports the management of a firm's tangible and intangible resources along a value chain, by integrating and coordinating all information flows of repetitive production processes. To date, the variability of construction operations, the uniqueness of projects and substantial deployment costs have inhibited the diffusion of this technology among small and medium construction firms. Building on Web capabilities, one of the many ERP tools, MySAP, has been marketed to small suppliers and subcontractors in the manufacturing sector. Differently from its predecessor, the new application focuses on discrete operations of the entire value chain, offers standardized procedures and file formats, and entails lower deployment costs. It offers the opportunity of economizing on several of the supporting activities and resources of a construction firm's production operations.

CONCLUSIONS

Web-based technologies are changing the business operations of construction firms, notwithstanding the recent demise of many start-up companies. This paper has outlined some of the emerging business configurations and the need for theoretical frameworks to interpret and understand some aspects of such a phenomenon. These theories are useful for assessing the nature of construction transactions and the importance of long-term business relationships and optimizing in-house resources by outsourcing non-core business operations.

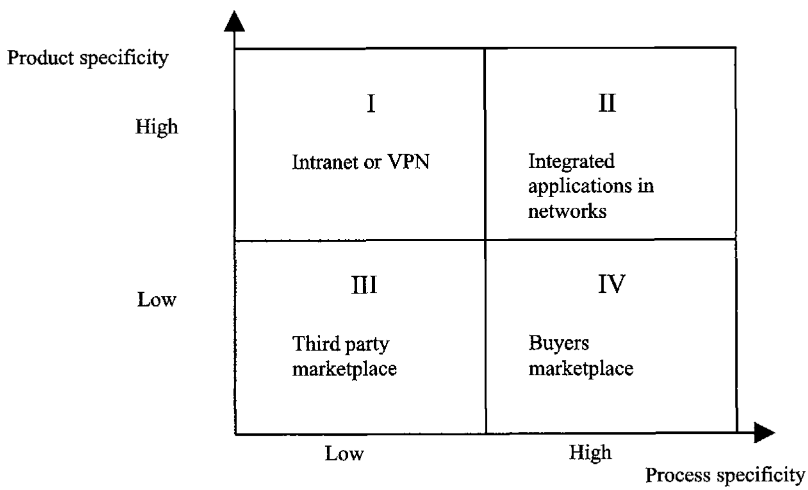

Figure 2 Possible uses of Web-based technologies in the construction procurement process

The considered theories could be the starting point for future detailed studies of the interaction between Web-based technologies and evolving business operations. Figure 2 shows a possible application of these theories to understand the varying approaches of firms to the adoption of Web-based technologies. The interpretative four-quadrant chart of Figure 2 is based on two important dimensions of the transaction cost approach: product specificity (the extent of the demand for specific and complex supplies and services) and process specificity (the extent of customization and repetition in meeting customer demand and requirements). In the case of low asset specificity, firms decrease search costs of spot transactions by joining third party marketplaces (Quadrant III). In the case of repetitive transactions (of the same supply) over time, firms develop more standardized purchasing procedures to take advantage of scale economies by establishing their own marketplace (Quadrant IV). When transactions are characterized by high asset specificity (a frequent situation in construction projects), it is convenient to develop collaborative links between buyers and sellers within the boundary of a private network or Intranet (Quadrant 1). The benefits of cooperation and privacy justify the development of shared exchange procedures and information technology applications among a network's parties. If stable cooperative relations and repetitive transactions emerge over time, a network optimizes the resources of participating firms by developing integrated and standard process procedures, such as those offered by ERP applications. This interpretation is in line with existing business arrangements in the US construction industry. Third-party marketplaces are convenient when commodity-like supplies are exchanged on a spot basis. When the exchange is more complex, contracting firms rely on partners with which they have a long-lasting work experience.

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WEB-BASED CONSTRUCTION PROJECT MANAGEMENT: CURRENT STATE, TRENDS AND POTENTIALS

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ABSTRACT

With the beginning of the new millennium, the construction industry has entered into a new era. The concept of managing construction projects using web-based techniques seemed like a mirage just a decade ago, but now is much closer to reality. Contractual, organizational and informational integration in the process of construction can be achieved effectively by the use of Internet and related (such as Intranet and Extranet) technologies. In this paper, a review of current and emerging web-based techniques and methodologies, such as virtual on-line design studios, on-line bidding, on-line project administration, on-line building products catalogues, and project monitoring and control through the use of web-cams is presented. Emerging trends in the field of construction project management with ICT (information and communication technology) are examined and highlighted. Represented case studies from published sources are included in support of the conclusions made.

IMPACT OF INFORMATION TECHNOLOGY ON CONSTRUCTION

Construction is a multi-organizational process that is heavily dependant on exchange of large and complex data. Successful completion of a project depends on accuracy, effectiveness and timely communication and exchange of critical information and data between the project teams (Akinsola *et al.* 2000). The need for effective information processing and exchange increases with the increasing degree of task-uncertainty, number of organizational units involved, and extent of interdependence among the units. By sharing information within the organizational units as well as among the participating organizations significant integration in construction processes can be achieved (Ahmad and Ahmed, 2001).

In the construction industry, information technology (IT) is creating new possibilities and, as a result, its advancement is placing new demands upon design and construction organizations. IT can no longer be viewed as an enhancement to traditional construction procedures but rather as an innovative agent that enables new and different alternatives to organizing and operating construction enterprises. As a consequence, construction organizations are faced with opportunities as well as challenges (Ahmad *et al.*, 1995).

Current and emerging IT capabilities can be grouped into three broad categories: information management and services, communications and processing/Computing as shown in Fig. 1.

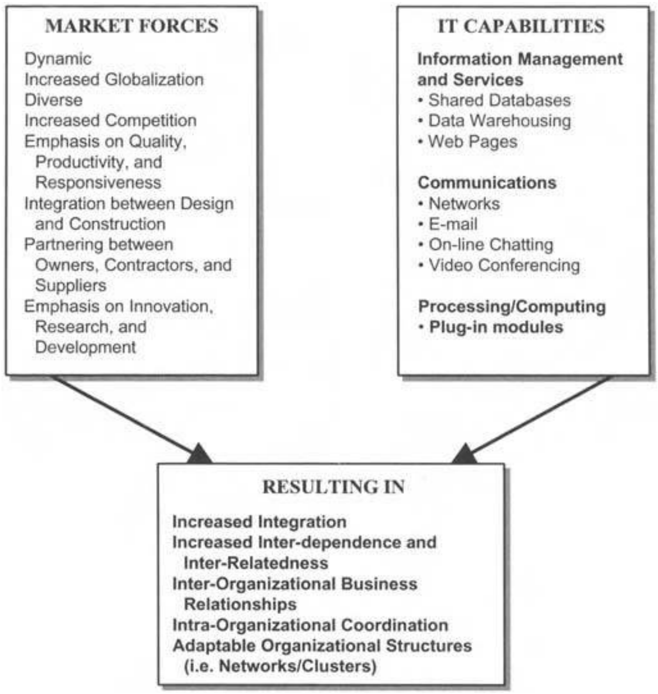

Figure 1 Effect of market forces and it capabilities on design and construction organizations (Derived from Ahmad *et al.,* 1995)

This grouping of IT capabilities is based on the usefulness of IT from a user perspective (Ahmad *et al.*, 1995). Each of these IT capabilities is briefly explained in the following sections.

Information Management and Services

Information management component includes all aspects of IT for capturing, storing, organizing, and retrieving data. Internal (project/company) and external (industry) standards are essential for maximum integration in the process. Shared databases, data normalization techniques, data warehousing, barcode technology, CAD graphics are examples of advancement in this area (Ahmad and Ahmed, 2001).

Majority of construction companies are now utilizing Internet as one of the effective and efficient advertising tool. The information advertised in a company Webpage typically includes the company profile, services or products, recent projects, job vacancies and public feedback forum. Intranets are also used to provide information presented for the benefit of the employees, such as the company policy, employees' directory, newsletters, and manuals. Extranets can be used to present information regarding an outgoing project to the business partners, such as the project description, contract documentation, project documents, and project directory (Skibniewski and Abduh, 2000).

Communications

The communications area includes all aspects of communicating data and information such as text, graphics, audio and video. The most common communication tool is electronic mail. The different chatting softwares such as ICQ™, IRC™, Net Meeting™ etc. are also frequently used to allow seamless discussion between two or more parties involved in a particular session, e.g. when the contractor and the engineer need to discuss a solution to an urgent problem encountered on the jobsite. Hyper Text Markup Language (HTML) can also be used for simple communication such as the use of forms, e.g. to send work progress information from the field, which can then be used for the preparation of progress reports (Skibniewski and Abduh, 2000).

Communication tools can help design and construction organizations to coordinate their activities with greater effectiveness and efficiency overcoming the barriers of time and distance. Training tools, such as multimedia, can help train workers. However, there is a profound need for uniform and standard data in the construction industry. Without standard data it is difficult to establish a common performance measurement system or a uniform quality assurance program. Uniformity of procedures and standardization of data would greatly enhance the effectiveness of communication among the multiple construction organizations teaming up to build one constructed facility (Ahmad and Ahmed, 2001).

Processing/Computing

Processing includes all systems and models developed for processing data. Technologies supporting the process of developing such systems and models underlie this component of IT capability.

By the advancement of scripting technologies on both the client side and the server side as well as through the availability of plug-in modules, the Internet (including Intranet and Extranet) can be used for engineering and management computing purposes. The most common examples include project scheduling, resource management and project cost control using shared databases through Internet (Skibniewski and Abduh, 2000).

THE WORLD WIDE WEB (WWW) AND THE CONSTRUCTION INDUSTRY

Despite an explosive growth of the Internet usage during the last five years in many areas of business and commerce, the construction industry has not kept pace to the same degree. However, many large construction firms have now entered the Internet age. The basic Internet services such as electronic mail, remote login, file transfer, network news, and the World Wide Web have become familiar tools for majority of construction managers. These current trends constitute new opportunities that can be used to improve construction processes (Skibniewski and Abduh, 2000).

When the WWW browsing era initially emerged, application development required significant programming knowledge. This consideration alone stagnated application development from most non-computer gurus ends. With the current emergence and influx of easy to use application development tools, the development of web-based applications has ceased to be a hindrance to effective IT exploitation in current applications. Now construction managers can access specific project information in desired formats in an accurate, timely, and pertinent form from anywhere across the globe and this too at particularly any time. If so setup, they can even view live happenings at the site location without physically being at the site, in its city, or even country (Kazi, 1999).

Today, the web is not only used to display text and to provide hyperlinks to display the text. It also becomes a dynamic client/server system and a universal medium that can handle several communication protocols that had to be handled previously by several dedicated systems. Web browsers are playing important roles in providing dynamic and universal client programs independent of machine and running platforms (Skibniewski and Abduh, 2000).

WEB-BASED CONSTRUCTION PROJECT MANAGEMENT

The convergence of information services, communication and computing functionality in the Web technologies allows practitioners in construction to perform a Web-based project management over the Internet. A number of construction companies all over the world have adopted this technology either because they realized its competitive advantages or they are being forced by their clients to adopt it (Skibniewski and Abduh, 2000).

From the numerous Web-based construction project management applications, some of the significant ones are highlighted in the following sections.

Virtual On-line Design Studios

The virtual design studios allow designers and experts from different places to interact using audio and video conferencing. They can also share the same screen and same program thereby entering the same virtual reality space. This allows discussing virtually any matter without the need to travel. An illustration of such system is shown in Fig. 2.

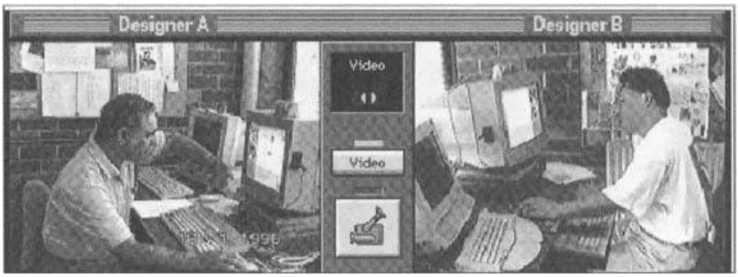

Figure 2 Virtual on-line design studios (Source: Turk, 2001)

On-Line Electronic Bidding Systems

One-way electronic bidding systems already are in wide use. These allow bid packages to be downloaded from a Web site with bids returned on paper, sometimes with a requirement that files on disks accompany them. However, recently some companies have developed on-line systems to facilitate Two-way bidding, i.e. bid documents can be submitted as well as edited on-line before the bid-closing date. This will reduce lot of paper work resulting in time and cost savings.

One example of such on-line bidding systems is *Bid Express*™ developed by the Info Tech., Inc. The Bid Express™ is operated through the web-site http://www.Bidx.com. The Georgia Department of Transportation (GDOT) is using this system for all bids more than $500,000. Contractors that want to submit the bids over the web must subscribe to *Bidx.com*, which costs $25 a month, and must have a digital signature on file at the exchange side. They submit bids as encrypted files to be held in an electronic lockbox until the deadline. When the time comes, the box contents are downloaded by the GDOT, which uses electronic keys provided by registered contractors to open the bids. Until the moment of delivery, the GDOT does not have access to the bids and the exchange service does not have the service to decode them. This setup ensures the security of the system to stop any act of fraud and hacking. Figure 3 explains the operation of Bid Express™.

This two-way on-line bidding system allows the contractors to edit their bids till the last moment to make any necessary adjustments, which could be worthwhile like the following case.

> *"Late on night last year, a Kentucky speciality contractor bidding a $2-million guardrail job in Georgia learned that one of its suppliers had dropped a key price. The bids were scheduled to be opened in just a few hours in Atlanta, and the contractor had to act fast. The company president didn't sweat it. He went on the Internet, recalled his bid, changed it and won the work (Sawyer, 2001)"*

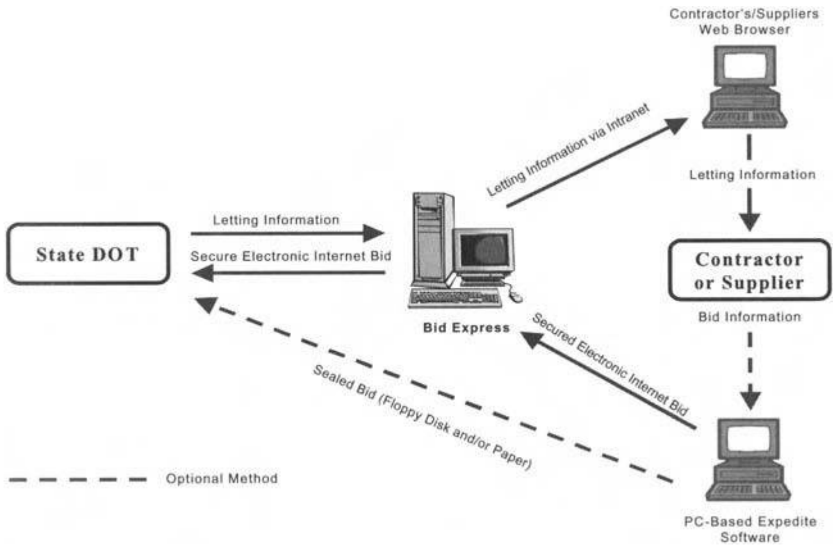

Figure 3 How the Bid Express™ works? (Source: http://www.bidx.com)

On-line Project Administration Systems

The on-line project administration systems can provide round the clock information about the project such as project status; directory of contractors, consultants, vendors and suppliers; project drawings and specifications; project control reports and the facility to submit on-line change orders. A number of construction companies are adopting such systems to facilitate better communication between the head office and the remote project sites, which could result in both time and cost-savings. One excellent example of the use of this technology is the construction of Sashiki bridge project in Kumamoto Prefecture, which was located at a very remote site. The introduction of Web technology provided a way to make dispersed construction groups to work collaboratively together as an effective single team sharing pictures, documents, and real-time videos (Hirai *et al.*, 2000).

Different software companies have developed on-line project administration systems and details can be found in any good construction magazine such as *Engineering New Record.*

On-line Building Products Catalogues

On-line building product catalogues, also known as Web-based catalogues have become major building product information sources on the web. The content of information in these catalogues include performance data, standards and specifications, installation instructions and the facility to place on-line orders. Most on-line catalogues organize and present product information in a format and detail that is useful is construction documentation thereby saving time and effort Moreover, they allows CAD users to call up graphical directories of elements used in their current design project and examine product descriptions and specifications that are available on the WWW. (Coyne and Lee, 2000). An example of such system in illustrated in Fig. 4.

Project Monitoring and Control Through Web Cams

Using dedicated video cameras to remotely monitor construction sites through the Internet may seem like a small jump from ordinary security surveillance, but the Web-cam's unblinking eye may be key to a project management revolution. Among other things, the round-the-clock digital views and archives of project progress are serving as impartial dispute arbiters. The Web cams provide continuous pictures regardless of weather and safety conditions and save hours or even days of travel time. Moreover, all images are recorded for archiving and have date and time stamps.

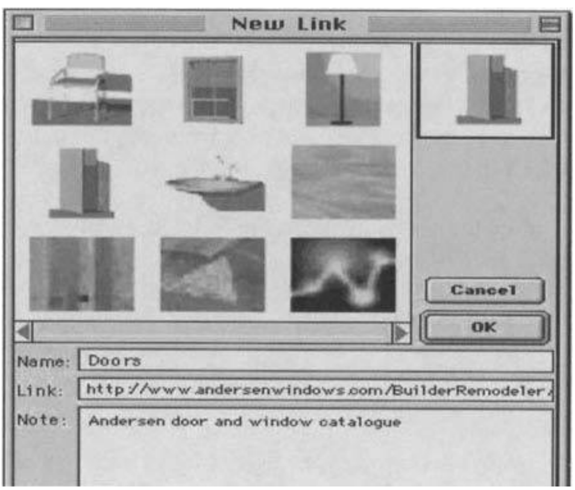

Figure 4 An on-line building products catalogue

(source: http://www.caad.ed.ac.uk/Coyne/ProductCatalogReport/plaid.htm)

CSR Nevada, LLC a Las Vegas based company recently used the images of web-cams as evidence in a court-case as stated by their viewmaster (Angelo, 2001).

> *"Our recordings were recently used in court to settle a dispute involving teamsters be the activity" locking a construction site. The court viewed the evidence and ordered them to ceas*

A typical construction site uses three cameras, two stationary and one pan tilt, which costs $10,000 to purchase, install and set up (Angelo, 2001). The cameras typically shoot one picture per hour but the system can handle as many as one shot every 30 seconds. The pictures are transferred through Internet to the company's head office or wherever required. Figure5 depicts a real-life use of Web cam in a construction site.

Web cams could become more popular as project participants recognize their importance in project monitoring and dispute resolution. According to Angelo (2001), Web cams typically can help resolve critical-path delays caused parties or by an Act of God such as floods. They can also be used to stop workers' compensation fraud.

SETTING UP WEB BASED PROJECT MANAGEMENT SYSTEM

When a construction company commits to adopt a Web-based project management system, there are two possible strategies that the company can choose in developing the system: in-house development or outsourcing this activity to a professional consultant (Skibniewski and Abduh, 2000).

Regarding the first option, the company needs the following software, hardware and interfaces.

1. Powerful server for computing and transferring information.

2. Internet, Intranet or Extranet availability to access information within project circle with maximum security.

3. Web-based construction project management software specially developed keeping in mind the company's organizational structure and needs.

The second option is useful for companies with limited resources to develop their own Web-based project management systems. Consultants may be hired to build a Webpage to fulfil the company's Internet advertising needs. For other services, commercial Web-based softwares such *Webster for Primavera*™, *AdvatnageNET*™, etc. can be used.

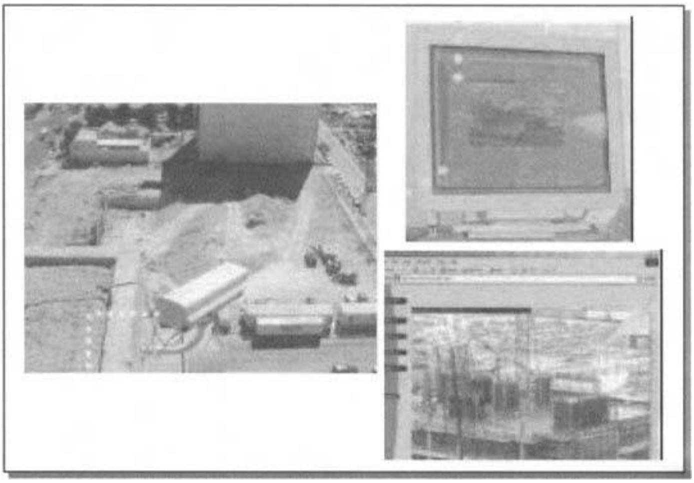

Figure 5 On-line project monitoring using Web cams (Source: Angelo, 2001)

CONCLUSIONS

Despite exponential growth and widespread application in almost all industries, particularly manufacturing and services, the Web-based technologies have only recently been introduced in the construction industry. It was shown in the paper, that significant benefits could be realized by developing appropriate Web-based solutions and applying them correctly to construction industry problems. Construction firms and construction project site offices can be run more effectively and a greater cost-saving can be materialized with the use Web-based techniques. The technology is maturing and getting more affordable day-by-day creating an unprecedented opportunity for effective project management in construction.

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INCREASE OF EFFICIENCY OF CONSTRUCTION MATERIALS E-COMMERCE SYSTEMS APPLYING INTELLIGENT AGENTS

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ABSTRACT

To find the rational quality and price, consumers need to visit many potential e-malls to compare multiple alternatives. If an e-mall can provide all comparable alternatives, the customer can find the rational selection by comparing the alternatives within the e-mall. However, this is not the case in most shopping. Visiting many e-malls sitting in front of a computer is a very time-consuming task. It is complicated matter to compare the alternative products in different e-malls. So customers need a complex supporting tool like intelligent agents for this purpose. Therefore, efficiency of e-commerce may be increased applying the intelligent agents. This article is indented to provide how application of intelligent agents developed by authors could increase the efficiency of e-commerce of construction materials.

THE INTELLIGENT AGENTS AND E-BUSINESS SYSTEMS

Intelligent agent is a software that can automatically contact different e-malls on the Internet, search for construction product information, and report the results.

Intelligent agents can help to determine what to buy to satisfy a concrete need and where to buy it. This is achieved by looking for specific construction product information and critically evaluating it. Consumers specify requirements and constraints and the system returns a list of construction products that best meets their needs.

Intelligent agents help consumers decide where to buy by comparing construction products' offers. The customer queries the price of a specific product from a number of online sellers and returns a list of prices. However, this method has encountered many problems because sellers who do not want to compete on price only have managed to block out the intelligent agent's requests.

Customers wanting to buy a construction product assign the task to an intelligent agent, who is then sent out to seek sellers. In creating the search task, customers must specify constraints including technical and quality requirements, desired price, higher acceptable price, and a date by which to complete the transaction.

Previously, many intelligent agents roles were undertaken by the customer. Electronic commerce is increasing the value of intelligent agents by expanding access to customers, and by making the role economically viable. Intelligent agents create value by reducing the search effort for a construction product that will meet the customer's technical and quality requirements at an attractive price. The value of intelligent agents grows with the number and complexity of available choices. Thus, intelligent agents, create values by searching for construction product information and bargains and by checking inventories to determine which construction products are available. Customers enter descriptions of construction products they want to buy and let the bot do the shopping. Bots reduce the selection and delay risks for the customer, save time and finance resources. These intelligent agents provide detailed information on construction products, and help consumers to comparison shop and they help in a bidding war for the customer's business. These services all add considerable value for online construction products customers.

A BRIEF REVIEW OF THE CONSTRUCTION PRODUCTS E-BUSINESS SYSTEMS

Many e-commerce systems are seeking to find out the most economic decisions, i.e. most of all they are intended only for economic objectives. However the alternatives under evaluation have to be evaluated not only in economic position, but taking into consideration the qualitative, technical and other characteristics too. For example, the analysis of alternative construction materials is being usually performed taking into account price, discounts given, thermal insulation, sound insulation, harmfulness rate to human health of materials, aesthetic, weight, technical specifications, physical and moral longevity and other factors.

Today there are a great number of directories and electronic commerce systems, in the world related to construction products construction. Some of the well known websites are: www.needproducts.com, www.4specs.com, www.buildscape.com, www.commerce.net and www.sri.com.

The main functions of the most advanced Construction Products E-Business Systems are as follows:

- Construction product merchandising - construction products need identification; construction product presentations, pricing and personalized discounts, substitute products, search for the product or groups of products, finding of alternatives and formation of a comparable table/tables, construction product comparisons and buyer assistance for making construction product selections.

- Order management - execution of the orders application, selection of the form of payment, transfer of the order, payment for the order, receiving information about the state of a personal customer's account such as checking of availability of the required amount of money in account, checking of the order payment, shipping, inventory, and taxation; support for authorization, settlement, subscription renewals, partial billing, and credit payments.

- Fulfillment - deliver construction products with automated customer notification by faxes, e-mail, or secure Web pages; construction products receiving and verification. Reversible process: information is transferred to the server about the received construction products and an analysis of the results.

- Customer service - support customer service representatives with a set of tools for analyzing and resolving customer issues such as review of orders, payment history and billing information.

- Information exchange - announcement board, discussions forums, advertising, e-mail box, articles, other information, various announcements, notices, information of the market situation, market changes and future prospects, information bulletins and other updating information for the users' attention.

A brief description of some of the already mentioned functions of the construction products e-commerce will follow.

The exact need of construction products can be determined only when one has the building's project and requirements of the construction products which are specified in drawings and specifications of the buildings. The buildings construction projects provide a space for summarized operations schedules of the total construction products needed. Approximate needs can be determined by using construction standards designed for particular types of buildings. These standards show a ratio of average quantity of products to a unit i.e. square meter and cubic meter. After the collection of tenders/applications we know the required quantities of construction products, structures, products, dates and places of delivery and draw up plans for supplying the required products.

Regular buyers usually know what particular construction products they need. Therefore, they often skip the detailed catalogue browsing and proceed directly to a form of fast ordering. Before placing their orders buyers have to register, i.e. they have to get respective orders' numbers and personal passwords. During the process of registration consumers should specify the language they want to use during the electronic transaction and specify the place where they want the required products to be delivered.

Web pages of construction products shops have lists of products and links to related Web pages. When consumers decide to order products, they simply click an icon of the Order Form contained on each Web shopping page. Then, on their displays appears an application form in which they can place their orders. After filling out this Form and specifying all the products to be ordered and any other necessary details such as those required when filling out paper forms. Finally by clicking the Sent Order button, the order will be transmitted.

The Internet provides the possibility not only for completing money transfers but also for checking accounts.

The usual means of settling accounts in e-commerce is a credit card. Credit cards are now becoming the main form of making payments throughout the whole world. Electronic catalogues are often allied to the process of purchasing. Consumers can purchase construction products from the electronic catalogues by means of:

- Credit cards;
- Traditional cycle of payment such as order and invoice;
- Other schemes of payment e.g. electronic cheques.

When searching for construction products on the Internet, consumers may come across many different sources of information. If the consumers want to have access to the latest available information, they have to visit the supplier's or manufacturer's WEB page.

Efforts are being made to bring all the stages of e-commerce to an automatisation level and merge the stages into one single combination. For example, joining different suppliers into one unified network, and providing consumers with information about the available construction products, their stored amount in real warehouses and the possibilities of delivering the required construction products on time. In the absence of required construction products, alternative products are offered instead. Standardised forms are used during the process of doing e-commerce, which help to carry out the electronic integration of all integral parts of this process. In practice, not only financial resources can be completely saved by applying e-commerce systems, yet, another advantage of using e-commerce systems is the strengthening of the competitive position of the user.

It is advisable to gather information on the frequency of the consumers' access to the e-commerce system for construction products. After accumulating and examining information such as what construction products and what information is in greatest demand among buyers and what type of transactions are buyers mostly interested in, it becomes possible to carry out a market analysis and project the further trends of the system's development.

Most often services offered by e-commerce systems to buyers are provided free of charge. Besides, it is widely maintained that the free e-commerce services will help new consumers to become accustomed to in general e-commerce. The suppliers and manufactures, however, have to pay for the information they provide. Some of the Web pages receive partial or entire maintenance of their service from advertisement money. The more information manufactures and suppliers provide about construction products offered for sale within the system of e-commerce. Information offered includes prices, specifications, technical and qualitative characteristics and information about discounts, the more valuable the information and service is to the consumers. The more frequently consumers use the system, the easier it is to convince new suppliers and manufactures to place their information about construction products into the system.

Aiming at enhancing mutual confidence and reaching more efficient problem solving, a dialogue between consumers and suppliers is constantly encouraged and maintained by means of electronic discussion forums. Each consumer within the system can make an enquiry on how to solve various problems which arise during the process of delivery of construction products and ask many all those other questions. Priority for consultations is granted to those consumers who can pay for such involved consultations. An example is when an annual agreement has been concluded regarding provision of consultations or technical support, the e-commerce system can help.

Every manufacturer or supplier involved in e-commerce may have their own personal server and database. Therefore, both suppliers and manufactures can constantly update the data they provide and the consumer can become acquainted with the latest information about existing construction products. If the supplier has got several warehouses and the nearest one lacks the required construction products, the system automatically checks the stock kept in other warehouses and offers bringing the goods from the warehouses. If the required construction products are not available in any of the warehouses, alternative products are offered.

Very often two databases are maintained. One of the data bases functions on a permanent basis and is used by the consumers, whereas the other one is being updated. Consumers can have access to the updated database. Every day consumers can also use the knowledge base with the experts' system providing assistance in solving their own various problems. The knowledge base may contain various articles, recommendations, standard documentation and more information.

Very often an integral construction products electronic catalogue is created, which enables a person to review all the products offered by alternative suppliers, place orders and make payments. Catalogues provide illustrations of the construction products, technical and economic parameters, specifications, textual information, instructions and sometimes three-dimensional drawings. The information stored in the database makes it easy to create vary and update electronic catalogues.

The database provides information about suppliers and their construction products, construction products prices, technical parameters, discount systems and more. The best solution would be if manufacturers and suppliers of the construction products would maintain the databases themselves.

An e-commerce system should operate in such a way that it ensures at the consumer receives the required information during the shortest possible period of time.

E-commerce provides many advantages, such as funds saving, because when using an e-commerce system it is no longer necessary to:

- Print catalogues on paper and send them by post.
- Operators to answer telephone calls or make telephone calls, concerning the construction products supplies. For example, dismissal of operators employed by suppliers and manufacturers who had to answer clients phone calls and provide them with the required information.
- Pay for telephone calls.

- There are many other benefits offered by e-commerce to consumers, for example:
- Consumers receive the latest and detailed information;
- Users of e-commerce can very quickly carry out a search;
- Possibility to find rational construction products;
- Users can use information/specifications and drawings retrieved from the database later in their activities;
- Acceleration of the process of delivery;
- The total construction products delivery process can be carried out using several languages;
- E-commerce improves the image of the consumer because Internet technologies are high-level technologies.

All the above-mentioned advantages of e-commerce enhance the competitive capacities and increases the number of consumers and users.

DETERMINATION OF EFFICIENT CONSTRUCTION PRODUCTS

Before purchasing construction products, it is necessary to analyze the alternatives. By doing this, we compare prices, available discounts and other features of alternative items offered both on the Internet and in traditional shops. We also have to make sure that the shops are reputable. Prices on the Internet shops are usually lower than those fixed by the traditional shops. When a person buys products via the Internet, he/she has to find and receive information about available warranties and make sure that suppliers will take back defective items. After analyzing these conditions and other aspects of e-commerce it is possible to purchase reasonably-price construction products, otherwise the product's price may go up without reason.

Since alternative construction products are described on a quantitative and qualitative basis, very often it is not so easy to determine the products efficiency, for example, weights and prices. Construction product's weight has great influence on the reduction of the price of a building. Weight is a constant load. The bigger the weight, the stronger the elements that a building has to withstand. Besides, weight means transportation and construction costs. The heavier an object the higher the price. Transportation expenses make up around 20% of the products' price. Total expenses of the products on average are around half the construction costs. That is why it is very important to use them economically. For example, if a company's profit reaches 6-7% of the construction price, then a 2% economy of products will increase the profitability up to 10%.

Therefore, one of the main enhancement trends of e-commerce efficiency is a search for required alternative construction products and a determination of efficiency, on the basis of one or several criteria or even a system of criteria. Consumers can find the required supplier or manufacturer according to different information.

When carrying out construction products search according to selected properties, the consumer diminishes his/her limits of the search. If the search restrictions are extensive, in some cases it will not be possible to find the required construction products at all, and vice versa. If no search restrictions have been imposed, the consumer will find too large a number of alternatives. In this case the search programmes help the consumer to determine the rational search parameters. This is done by providing information about what amount of products according to each set parameter is stores in warehouses)In this way the consumer can very efficiently carry out his/her search of the required products.

The consumer carries out a construction products search according to selected parameters

↓

The search program provides information about how many alternative products according to each set parameter, are stored in warehouses

↓

The consumer rationalizes construction products search parameters

↓

Finding alternatives and forming comparative tables

↓

Multicriteria analysis of alternatives

↓

Determination of the most efficient alternative

↓

Presentation of final results

Figure 1 Identification of efficient construction products.

For a consumer it is very useful to find all the alternatives offered from different suppliers or manufacturers catalogues, then later compare the catalogues and select the most efficient products. This is possible only if catalogues and the data's presentation forms are standardized according to certain levels. Such standardization provides conditions for applying intelligent agents that help to carry out a search for the required construction products in different catalogues, compile information about the products, present this information in a comparable table, compare the retrieved alternatives and make recommendations. Only an expert in this field can effectively perform such an enormous amount of work. Therefore, the role of intermediaries should become more important.

This can be explained by a simple example: Suppose that a contractor needs construction products of 1000 denominations for the realization of a contract. The efficiency of each construction product can be described by a system of criteria with real values and weight of those criteria. The search of alternative construction products has shown that there are 6 suppliers who have the required construction products. Suppliers are located at a distance of 5, 16, 36, 68, 120 and 157 kilometers from the site. These suppliers (taking into account the total amount of the order) give different discounts. There are also some other differences involved. Therefore, we can see that it is not so easy to identify efficient construction products. However, after an efficient implementation we would be able to save financial resources.

CONSTRUCTION PRODUCTS MULTIPLE CRITERIA E-COMMERCE SYSTEM

Following the ideas already mentioned and other ideas, the authors developed a Construction Products Multiple Criteria E-Commerce (CPMCEC) System.

The proposed CPMCEC System can create value in the following important ways:

- help customers assess their needs,
- identify suitable offers to fulfill needs,
- compare and evaluate offers,
- match a particular offering to the customer in an attempt to get the 'best deal' for the customer,
- help customers evaluate the usefulness of the product in the after-purchase evaluation stage.

In sum, the proposed CPMCEC System creates greater convenience and provides better choices for buyers throughout the purchasing process.

A general purchasing decision-making model for consumers includes five principal stages as follows:

- demand identification,
- information search, and evaluation of alternatives,
- purchase,
- delivery,
- after-purchase evaluation.

Efficiency of some above-mentioned stages may be increased by applying the CPMCEC System for e-commerce of construction products, as suggested by the authors. How is such a process viewed in cyber-space?

At the present moment the developed CPMCEC System allows the performance of the following functions:

1. Search of construction products. A consumer may perform a search of alternatives from catalogues of different suppliers and producers. This is possible since the forms of data submitted are standardized into specific levels. Such standardization creates conditions to use special intelligent agents who perform a search of the required construction products from various catalogues, and gather information about the products. One or several regions may limit such search.

2. Finding out alternatives and making comparative tables. Consumers specify requirements and constraints and the System queries the information of specific construction products from a number of online vendors and returns a price-list and other characteristics that best meets the consumer's desire. The System performs the tedious, time-consuming, and repetitive tasks of searching databases, retrieving and filtering information, and delivering the information back to the user. Results of a search of specific construction products are submitted in tables, which may include direct links to a Web page of a supplier or producer. By submission such a display, of the multiple criteria comparisons can become more effectively supported. The results of the search of a concrete construction product are often provided in one table where one can sometimes find direct links to the Web page of the supplier or manufacturer.

3. Evaluation stages of alternatives (i.e. multiple criteria analysis of alternatives and selection of most efficient ones). While going through the purchasing

decision process a customer must examine a large number of alternatives, each of which is surrounded by a considerable amount of information (price, discounts given, thermal insulation, sound insulation, rate of harm to human health of the products, aesthetic, weight, technical specifications, physical and moral longevity). Following on from the gathered information the priority and utility degree of alternatives is then calculated. The utility degree is directly proportional to the relative effect of the values and weights of the criteria considered on the efficiency of the alternative. It helps consumers to decide what product best fits their requirements.

4. The after-purchase evaluation stage. A consumer evaluates the usefulness of the product in the after-purchase evaluation stage.

Various interested groups, i.e. producers, suppliers, designers, contractors, property and facilities management organizations, users, banks and other financial institutions, Internet services providers, standardization institutions and governing authorities, can apply the developed System in their practical activities.

PRACTICAL EXAMPLE

Residents of a multi-apartment dwelling wanted to change the windows of their apartments. All windows of the apartments are of the same dimensions. A consumer may perform a search of alternatives from databases of different suppliers. It is possible since the forms of data submission are standardized in a specific level. Such standardization creates the conditions to use the special intelligent agents performing search of the required construction material in various databases, and gathering information about them. Consumers specify requirements and constraints (see Figure 2) and the CPMCEC system queries the information of a specific window from a number of online suppliers. Results of search of a specific window are submitted in tables, which may include direct links to a Web page of a suppliers. By submission such a display, the multiple criteria comparisons can become more effectively supported.

Presentation of information in different types of construction materials Web pages may be in conceptual (digital, textual, graphical, photographic, video) form. Conceptual information means a conceptual description of the window alternatives, the criteria and ways of determining their values and weights. Conceptual information is needed to make a more complete and accurate valuation of the window alternatives considered. Conceptual description of the first alternative of window is presented in Figure 3.

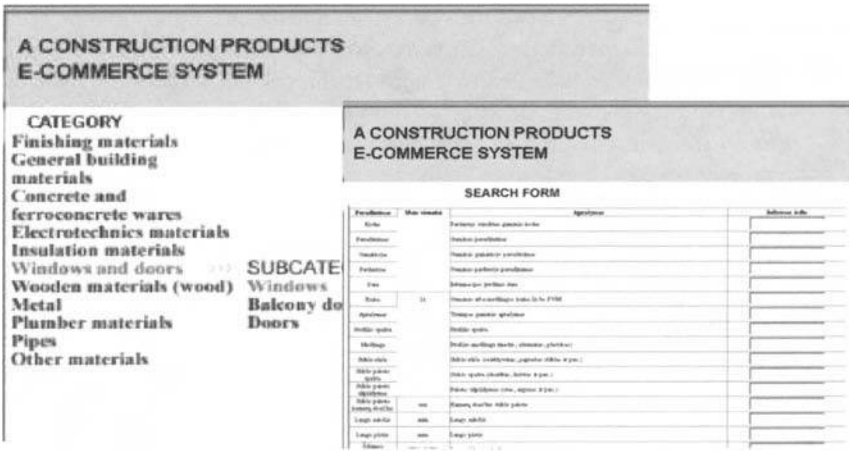

Figure 2 Consumers specify requirements and constraints and the CPMCEC system queries the information of a specific window from a number of online suppliers.

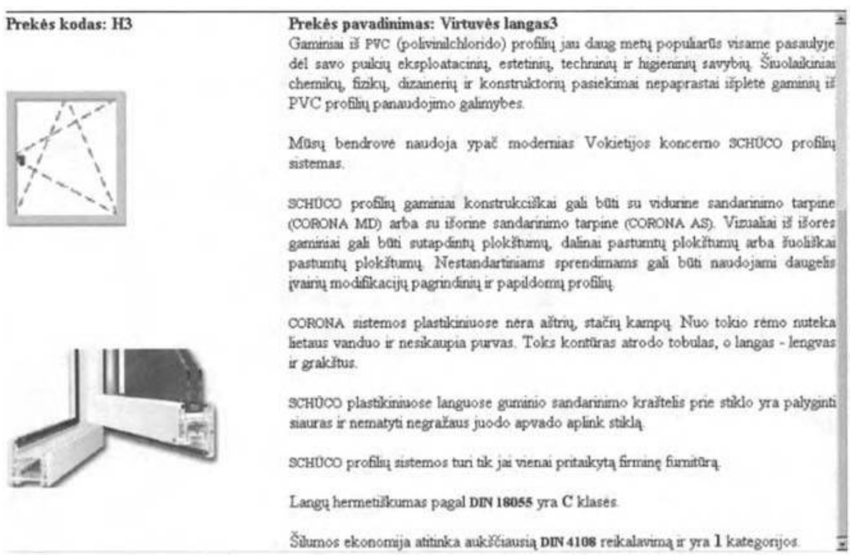

Figure 3 Conceptual description of the first alternative of window.

Residents are interested not only in price of windows, but in their quality as well. Since the dwelling is near a noisy crossroad, sound insulation of a window became an urgent priority. There is a tendency for regular increases of the price for fuel, and winters are cold in Lithuania. Therefore for all consumers the thermal insulation of windows gains greater importance. A guarantee period of windows is also important, as are other factors as well. Five suppliers (Hronas, Doleta, Roda, Alseka, Staliu gaminiai) have been found after making a search of required alternative windows, which offered 9 alternative windows (Fig. 4).

Kodas	Pavadinimas	Gamintojas	Pardavėjas	Data	Kaina Lt	Aprašymas	Profilio spalva	Medžiaga	Stiklo rūšis	Stiklo paketo spalva	Stiklo paketo užpildymas	Stiklo paketo kamerų skaičius vnt	Lango aukštis mm	Lango plotis mm	Šilumos laidumas W/(m2*K)	Garso izoliacija dB	Šviesos pralaidumas %
H1	Varstomas langas1	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	420	Tai vienas iš pigesnių variantų	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
H2	Varstomas langas2	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	661	Tai taip pat labai populiarus variantas	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
H3	Varstomas langas3	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	686	Labai patogus naudojimo atžvilgiu	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
H4	Varstomas langas4	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	637	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	20	0.89
H5	Varstomas langas5	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	963	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
H6	Varstomas langas6	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	989	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
D1	Varstomas langas1	UAB Doleta	DOLETA UAB Petras Petraitis	2001-07-03	800	Labai geros kokybės langai	Natūrali	Klijuota mediena (pušis)	Selektyvinis	Šviesus	Argonas	1	1520	1460	1.1	32	0.77

Figure 4 Five suppliers have been found after making a search of required alternative windows.

Decision making matrix formed in the second stage, shows found alternatives. Based on this decision making matrix it was possible to define the most efficient variant. Each criterion goes together with its measurement unit and weight. The magnitude of weight indicates how many times one criterion is more significant than the other, in a multiple criteria evaluation of window refurbishment. The calculations revealed that the key factors which have affected the efficiency of window refurbishment are: cost (weight q_1=1.0), heat conductivity (q_2=0.54), sound insulation (q_3=0.21), guarantee period (q_6=0.12) and more.

Quantitative information presentation involves criteria systems and subsystems, units of measurement, values and initial weight fully defining the variants provided. Quantitative information of windows is submitted in a form of grouped decision making matrix, where the rows mean n windows under valuation, and columns include quantitative information. In this way, the system enables the decision maker to receive varied conceptual and quantitative information on windows from a database and a model-base, allowing him/her to analyze the above factors and make an efficient solution.

Since the analysis of windows is usually performed by taking into account economic, quality, technical, legal, social and other factors, a model-base should include models which enable will a decision maker to carry out a comprehensive analysis of the variants available and make a proper choice. The following methods (models) developed by authors are aimed at performing the next functions:

- A method and model for criteria weight establishment. A new method of complex determination of the weight of the criteria, taking into account their quantitative and qualitative characteristics was developed. This method allows calculation and co-ordination of the weight of quantitative and qualitative criteria according to the above characteristics.

- A method and model for multiple criteria analysis and setting priorities. A new method of multiple criteria complex proportional evaluation of the construction materials, enabling the user to obtain a reduced criterion determining complex (overall) efficiency of the material was suggested. This general criterion is directly proportional to the relative effect of the values and weight of the criteria considered of material's efficiency.

Kodas	Pavadinimas	Gamintojas	Pardavėjas	Data	Kaina Lt	Aprašymas	Profilio spalva	Medžiaga	Stiklo rūšis	Stiklo paketo spalva	Stiklo paketo užpildymas	Stiklo paketo kamerų skaičius vnt	Lango aukštis mm	Lango plotis mm	Šilumos laidumas W/(m2*K)	Garso izoliacija dB	Šviesos pralaidumas %	Šviesos atspind %
H1	Virtuvės langas1	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	420	Tai vienas iš pigiausių variantų	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.[illegible]
H4	Virtuvės langas4	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	637	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.[illegible]
H2	Virtuvės langas2	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	661	Tai taip pat labai populiarus variantas	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.[illegible]
H3	Virtuvės langas3	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	686	Labai patogus naudojimo atžvilgiu	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.[illegible]
H5	Virtuvės langas5	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	963	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.[illegible]
H6	Virtuvės langas6	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	989	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.[illegible]
D1	Virtuvės langas1	UAB Doleta	DOLETA UAB Petras Petraitis	2001-07-03	800	Labai geros kokybės langai	Natūrali	Klijuota mediena (profis)	Selektyvinis	Skaidrus	Argonas	1	1520	1460	1.1	32	0.77	0.1

Figure 5 Multiple criteria analysis of window alternatives and selection of most efficient ones.

While going through the purchasing decision process a customer must examine a large number of alternatives, each of which is surrounded by considerable amount of information. Following on the gathered information the multiple criteria analysis are being carried out (see Figure 5).

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Integrated Intelligent Planning and Scheduling in the Construction Material Supply Chain Environment

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ABSTRACT

This paper describes ongoing research for developing an integrated intelligent tool based on multi-agent system, to support the planning and scheduling activities of a supply chain environment. The multi-agent system views the planning and scheduling activities as a collaborative reasoning process, and employs concepts from collaboration such as negotiation and information sharing to organize and coordinate the planning and scheduling activities. The multi-agent system is applied to support the planning and scheduling activities of a material supply chain. The research is motivated by the need for a methodology and information technology tools to support and automate the integration of planning and scheduling activities, and also the fact that planning and scheduling activities characterized by negotiation and collaboration between contractor and supplier/sub-contractors. It will further address the need for interoperability for the many heterogeneous software tools that abound the material supply chain.

INTRODUCTION

Over the past decades, the construction industry has experienced a growing need to improve coordination in order to enhance the performance of the material supply chain processes. The construction material procurement process consists of several participants and activities, and their interaction and interfacing need special attention. These activities are becoming increasingly difficult to plan and manage, with demanding customers often with tight budgets and schedules, complex technology, and supply chain teams that work concurrently in different geographical locations. Traditionally, the management of such processes has been done manually, but this leaves room for mistakes. Consequently, planning and scheduling tools has been deployed to tackle this arbitrariness in the processes. However, such solutions are generally incompatible with one another and unresponsive to changes, and to a large extent, have failed to address the key need of the industry – that of support for collaboration between its multi-disciplinary participants (Ndumu and Tah, 1998).

The advent of Distributed Artificial Intelligence (DAI) (Chaib-draa, 1995) has brought an added dimension to distributed decision making capabilities. However, it is the DAI's sub field of Multi-Agent System (MAS) that involves solving distributed problems through decomposition of agents that can communicate and collaborate in order to revise plans, schedules and decisions that the industry needs, to tackle the collaboration, planning and scheduling problems which are further complicated by the distributed nature of modern businesses and organizations. This paper presents an ongoing research that is investigating the application of agent technology to collaborative decision-making in material supply chain. The paper discusses the general notions of planning and scheduling in a material supply chain environment and a case for agent technology in this domain. An analysis and design of the system for the domain is presented and discussed. Finally, the paper describes a door assembly scenario and concludes with an outline of future direction for further work.

Element of Planning and Scheduling in Construction Projects

This section outlines the importance of planning and scheduling in a construction project context. According to Laufer et al (1994) analysis, there are four major project management functions of which planning and scheduling are part of it. Planning is discussed as the process of selecting and sequencing activities, such that they achieve one or more goals and satisfy a set of domain constraints. Scheduling on the other hand is associated with durations and resources that are assigned to various activities, which make up the plan. These assignments must obey a set of rules or constraints that reflect the temporal relationships between activities and the capacity limitations of a set of shared resources (Shen and Norrie, 1999). In material procurement, planning should satisfy the project objectives, which is within time and budget. It involves the determination of material tasks or activities, their logical interrelationships with each other, and the duration and resources required to complete material procurement activities. Planning in material supply chain involves the identification of activities based on the work breakdown structure (WBS) and relationships among activities; then the duration and resources required for each activity are estimated. The final stage of planning is the schedule computation result in terms of time and money that are used as baselines for the negotiation and delivery that will follow.

Project Planning and Scheduling Methods

According to Goldmann (1996), there are two different methods to planning and scheduling: The operations research (OR) approach, which provides tools for graphical planning and scheduling support. This approach range from simple bar chart such as Gantt charts to computerized network analysis such as CPM or PERT. The other method is the artificial intelligence (AI) approach of automatic planning and scheduling that additionally allows the industry to plan a problem by automatic application of predefined operators. Ugwu (1999) classified this approach into the following: expert systems, process planning and simulation systems and decision-support systems. The research work in artificial intelligence (AI) and operational research (OR) has addressed different aspects of construction material procurement activities. However, the existing systems are characterized by the following problems: current tools do not handle the distributed nature of the business process and lack facilities to manage the resources; current planning and scheduling system tools do not also have the ability to cope with dynamic changes in resource levels and task availability; existing systems have a limited or non-existent ability to plan the decomposition and re-combination of complex items; current planning and scheduling tools do not have the ability to generate qualitatively different ways of solving the specified task and the current tools are still based on single model and changes notification is primitive – meaning that all changes must be pre-specified usually by the user.

Requirements for next Generation Planning Systems

Given the major problems of existing systems, some distinct requirements of a suitable framework can be identified. The planning and scheduling system for this niche area should involve an inherent distribution of data, problem-solving capabilities, and responsibilities that conforms to the basic model of distributed, encapsulated, problem solving components. The adopted system should maintain the integrity of the existing organizational structure and the autonomy of its sub-parts. Since the business process deals with fairly complex situations, the system should have sophisticated interaction including negotiation, information sharing, and coordination. When taken together, the set of requirements leaves agent technology as the strongest solution candidate. An agent emphasizes certain attributes such as autonomy, flexibility (sociability, responsiveness and proactiveness), coordinating and high-level communication (Wooldridge and Jennings, 1995), which are relevant in a material procurement context (for example, co-operation and/or negotiation). However, the key issues related to integrated planning and scheduling systems, such as knowledge representation, ontology management, collaboration and communication, have been established in (Wooldridge and Jennings, 1995 and Nwana and Ndumu, 1996), and will not be discussed here.

RELATED WORKS

This section presents a brief review of intelligent planning research in construction and other sectors. Fischer et al (1995) described the MARS project on manufacturing planning and control that extended contract net protocol architecture for task decomposition and task allocation. The project demonstrated that auction mechanism used for scheduling could also be used for implementing dynamic re-planning. Goldmann (1996) described the Procura project for construction planning and design, in which agent acts as a central book-keeping mechanism which has to track all decision made inside the system. The result of their project facilitated the necessary re-planning and was able to track planning and scheduling as well as the actual design decision. In CEE-IDAC project, Tah et al (1997) applied MAS technology within the concurrent engineering environments. The system developed provided a common interface for the software agents to access information, solve problems cooperatively and contribute information to the blackboard architecture. MASSYVE project by Rabelo et al (1999) integrated multi-agent architecture with a federated database management approach, and their argument is that there is a focal shift of what is often seen as optimality scheduling to agility in scheduling. Petrie et al (1999) developed a novel approach for managing complex distributed projects based on 'Redux'. They showed how design, planning, scheduling, and construction can be interleaved and distributed, but still coordinated centrally. The project enabled distributed projects to be completed more quickly, and also start early with less complete information because of the system support change notification.

INTELLIGENT PLANNING AND SCHEDULING MODEL

The construction material supply chain environment is a world-wide network of contractors, suppliers, sub-contractors and manufacturers through which raw materials are acquired, transformed and delivered to clients. Its planning and scheduling activities consist of a number of related activities, which collectively realize some procurement need or project objective. Traditionally, approaches to planning and scheduling do not consider the constraints of both domains simultaneously. In spite of being sub-optimal, these approaches have been in vogue due to the non-availability of a unified framework (Shen and Norrie, 1999) However, the approach developed in this paper, provide a possible way of integrating planning and scheduling activities by adopting a decomposable "autonomous agents" approach to specify material supply chain model; models are represented as role models (Kendall, 1998), which constitute supply chain participants (e.g. suppliers, buyers and contractors), their structural relationships, interaction protocols and coordination policies. The role models of this domain describe the process by which resources are planned, produced and consumed. Some are simple, releasing a resource when it is demanded, while others are sophisticated variants involving some negotiation. The approach thus emphasizes construction of models that capture the existing structure and the autonomy of its sub-parts, thereby representing the complex and dynamic internal and external processes of organizations involved in the planning and scheduling activities.

Hence, it provides a framework that encapsulates the task decomposition, negotiation/commitment (scheduling) and delivery phase.

Planning Model (Task Decomposition)

The decomposition of material supply chain functions and their allocation to agents are amongst the initial tasks in project execution. This stem from the fact that when a Contractor is faced with a complex planning and scheduling problem, it usually solves it by reducing it into a set of smaller more manageable sub-problems. These sub-problems are, in turn, structured in such a way that a solution can be easily determined. This approach encourages us, to think of the problem in terms of role that need to be played, and the responsibilities associated with the role. In such a set-up, the activities can be modelled as a transaction between participants that are meant to carry out the tasks. At the highest level, a supply chain is made up of supply chain predecessors and supply chain successors. A predecessor can have many successors, as shown in the role model diagram in Figure 1.1. The figure illustrates that a supply chain participant is both a predecessor and a successor, while a supply chain head is a refinement of a predecessor and a supply chain tail refines a successor. Furthermore, Figure 1.2 shows a complete task decomposition/agent assignment phase and this will be based on how various participants intend to procure their tasks.

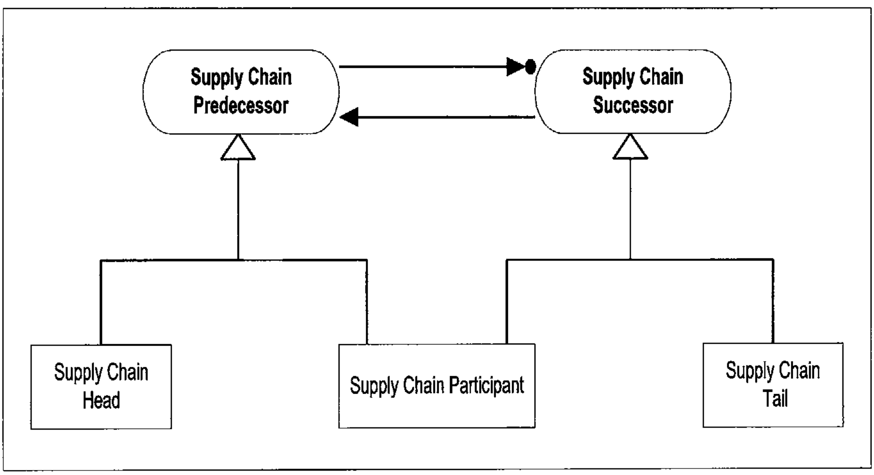

Figure 1.1 Supply Chain Role Model Diagram

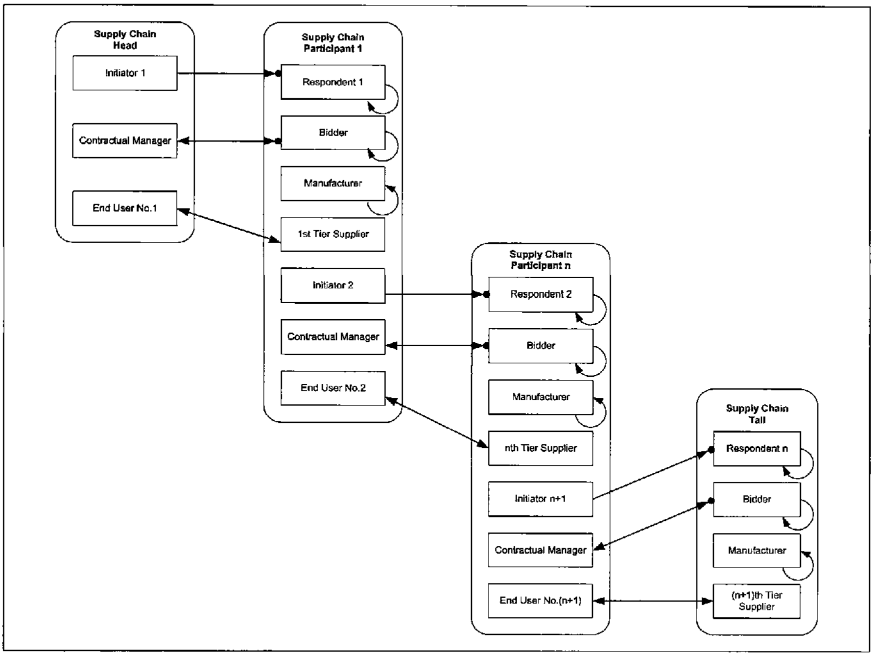

Figure 1.2 Task Decomposition and Interaction Diagram

Scheduling Model (Negotiation)

Negotiation is proposed as a means for agents to communicate and compromise to reach mutually beneficial agreements. The model here examines the problem of resource allocation and task distribution among autonomous agents, which can benefit from sharing a common resource or distributing a set of common tasks. Negotiation is initiated by the generation of a new task. This may occur when one problem solver decomposes a task into sub-tasks, or when it decides that it does not have the knowledge or data required to carry out the task. When this occurs, the agent issues out a call for proposal (CFP) message (see Figure 1.3). The arrival of a CFP message on the Supplier's side causes it to move into initialization state. If the Supplier agent decides to respond, it will move into negotiation state. The negotiation protocol in this model constitutes two approaches: a simple and contractual approach. The simple approach may be viewed as a generalisation of the contract-net-protocol (CNP) (Nwana and Ndumu, 1996). In CNP, task distribution takes place through a process involving manager task announcement, followed by bids from competing contractors and finally the announcement of awards. The contractual approach involves an interactive process of offers and counter-offers in which each agent chooses a deal which maximizes its expected utility value. The bidding prices commences low and increase while the asking price start high and decrease (see Figure 1.4). The figure depicts that the supplier will offer the material at the highest desired price, and then decreases this price according to the decay function (which is specified as being linear, quadratic or cubic). The converse is true with the Buyer as shown in the figure. Thus, during negotiation, the Buyer role of the supply chain predecessor negotiates with the Supplier in the successor. It involves request message sent out to all potential suppliers, who on their part have to agree to go into negotiation or refuse to negotiate because of other commitments. The final stage of negotiation, involve the agents applying their negotiation strategies to reach an agreement. This process commences at the supply chain head, and finishes at the supply chain tail (see Figure 1.2).

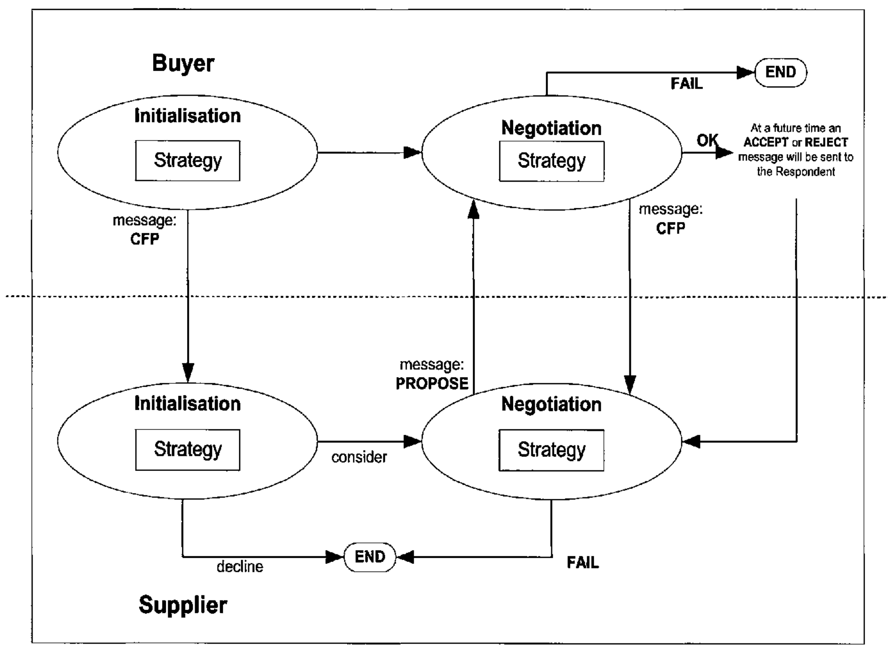

Figure 1.3 A Transition Diagram of a Typical Negotiation (Adapted from URL 3)

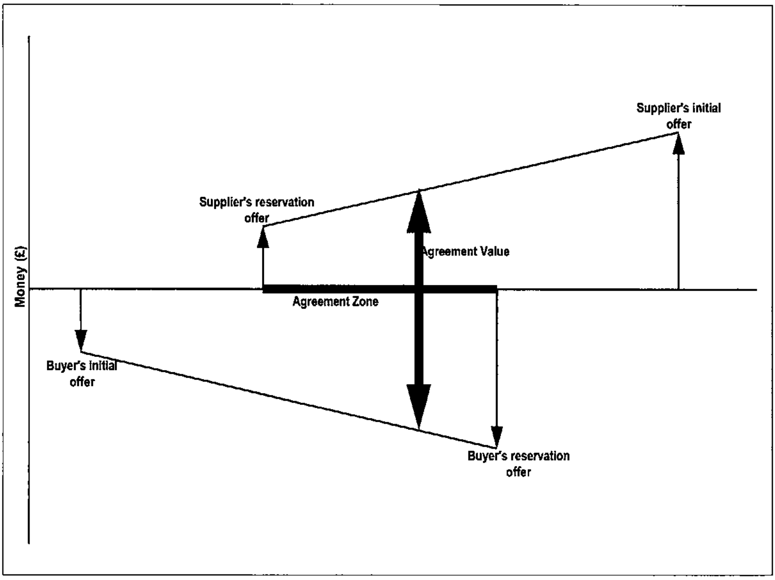

Figure 1.4 Contractual Negotiation Strategy

Delivery Model

This model enables the settlement aspect of trading to be separated from the negotiation model. The supply chain predecessor goes from being a Negotiation Initiator to a Consumer, and at the other end a supply chain successor is first a Negotiation Respondent, then a Producer, and then a Supplier (see Figure 1.2). If supply is agreed upon, the production and delivery of the resource follows immediately. This pattern is repeated for the length of the supply chain, as shown in Figure 1.2. During delivery, the activities starts at supply chain tail and ends at the supply chain head. Once agreement is reached during negotiation, the delivery phase is entered which also includes production.

MODEL IMPLEMENTATION

This section presents the system architecture for the supply chain environment that is developed to provide the basic platform for the planning and scheduling of the construction material procurement. The system implemented is aimed at establishing a network of software integration infrastructure by which geographically dispersed participants involved in different stages of the procurement are able to transparently interact, access and communicate various forms of information via their networked computers. In this approach, individual users adapt their software applications in the form of separate modules called agents using ZEUS building toolkit (Collis et al., 1998), and are arranged in loosely coupled autonomous/federated system architecture. The architecture developed here, utilises the ZEUS design philosophy, which provides the agent-level functionalities such as communication, ontology, coordination, planning, scheduling, task execution and monitoring. It further provides a virtual environment for developing the domain agents and information discovery (white and yellow pages) using ZEUS problem solving functionalities.

The domain agents can plan and schedule their activities as co-worker, peer and superior/subordinate agents. The co-worker represents agents of same organizational background and hierarchy, while the peer agents' represents agents of same hierarchy, but of different organizations. The superior/subordinate allows nested (hierarchical) agent system to be constructed in which higher-level agents realize their functionality through lower level agents (the lower level agents have the same structure as the higher level ones and can, therefore, have sub-agents as well as tasks in their agency). This approach enables flat, hierarchical, and hybrid organizations to be modeled in a single framework. The issue of agent discovery is tackled by configuring the information discovery (white and yellow pages) in ZEUS. The white page also known as Agent Name Server (ANS) is used to keep register of all agents in the environment and the yellow page also known as the facilitator is used as a look-up service for agents' abilities or expertise.

EXAMPLE SCENARIO

This section describes a simple example that uses ZEUS toolkit to construct a multi-agent application. The hypothetical scenario involves a number of companies required in the assembly of door-related products. Each participant in the scenario specializes in the assembly of a number of product lines, where each product may require components that need to be purchased from other companies. The first stage in creating this application is to analyse the problem scenario, part of this activity is the identification of candidate agents. In this case, the decision will be primarily based on existing organizational boundaries within the problem domain. The short-list of candidate agents and tasks at high-level are shown in Figure 1.5. The procurement process was simulated, by giving the contractor's agent the goal to assembly doors. However, this task is complex, requiring a number of subtasks that the contractor agent could not perform internal. Thus, the contractor agent decomposes the door assembly task into subtasks, which are contracted out to potential suppliers (see Figure 1.5).

In the task decomposition state, ZEUS toolkit is used to build-up agents, in which a resulting visualisation tool generates a Gantt chart showing the decomposition of the task, the allocation of its constituent subparts to different agents in the community, and when each agent is scheduled to perform its part of the task. Other task attributes that can be shown are their costs, the priority assignment to them by the agents, and the resources they require. The task decomposition/distribution graph created also shows the current status of each task, therefore either waiting, running, completed or failed. Thus, from the graph a user is immediately able to determine the overall status of a goal, and if the goal fails where exactly it did so. However, the preconditions of each task specify the resources required for the task, and its post conditions specify the expected effects of performing the task. All tasks have an associated duration and cost, which could be functions of the resources used or produced by the task (see Figure 1.6). In the figure, the link between tasks in the graph specify both precedence relation between the predecessor and successor tasks, and the resources produced by the predecessor task which are used by the successor task.

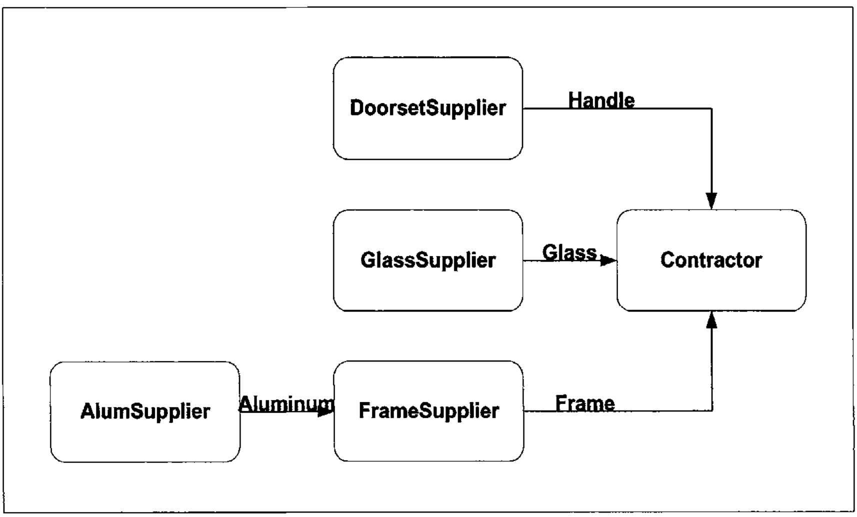

Figure 1.5 Supply Chain Participants of Door Assembly Process

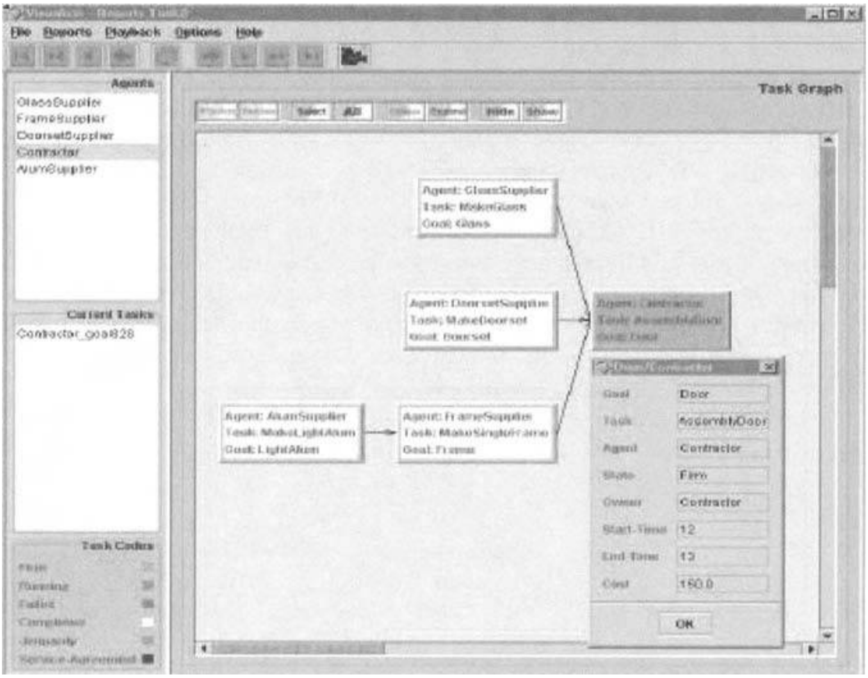

Figure 1.6 A Screenshot of Task Decomposition for a Goal to Assembly Doors

During contracting, the high level decomposition of agents is further decomposed into low level roles played by the same agents with different responsibilities (see Table 1). The table shows that agent contractor can play roles such as Initiator, Negotiator or Consumer, which represents activities of a buyer and the estimator in a contractor's organization. However, the scenario considers three task agents from the above environment, one representing the contractor's buyer and the others representing two suppliers bidding to provide the contractor with a component that make-up the AlumacoDoor (example Doorset). The process is triggered off by the contractor's agent (Initiator) requesting quote from potential suppliers (Respondent). The arrival of the announcement causes the Respondent to move into initialization state. If the Respondent decides to respond, it will move into negotiation state. In which case the process of negotiation is now passed on to the Negotiator role-play. The negotiation strategy adopted in this example follows the contract-net coordination protocol, where the contractor's agent (Negotiator) ask potential suppliers to submit quote for the material in question. On receiving the quote, the contractor's agent evaluates the quotes and award contract to the winning agent. In this simulation, the selection of the winning agent for the supply was based on cost only, although other factors such as quality, previous performance, environmental issues etc. could have been used in the selection criteria.

Table 1 Low-Level Role Description/Decomposition Table

Agent Name	Role Played
Contractor	Supply Chain (SC) Head (Initiator, Negotiator, Consumer)
FrameSupplier	SC Participant (Respondent, Negotiator, Supplier, Producer Initiator, Consumer)
GlassSupplier	SC Tail (Respondent, Negotiator, supplier, Producer)
DoorsetSupplier	SC Tail (Respondent, Negotiator, supplier, Producer)
AlumSupplier	SC Tail (Respondent, Negotiator, supplier, Producer)

FURTHER WORK

The above scenario on intelligent planning and scheduling has demonstrated how MAS can facilitate planning and scheduling between participants of a distributed material supply chain (SC) environment. However, the paper has kept the implementation details simple enough to demonstrate an understanding of agent interaction and processes. The research is specifically investigating agent-based planning and scheduling using material SC environment as a convenient test-bed. This involves intensive contracting between different participating agents in order to arrive at a feasible optimum solution that satisfies the project constraints. Such planning scenario is complex and may also involve interfacing with standalone systems (such as MS Project, Excel and MicroStation) used by various participants involved. Future work in this area will be focusing on the interface between the domain agents and external resources (such as the standalone tools). Furthermore, a key component in achieving interfacing with the external systems will be to scale-up the ontology that describes how a high-level task is decomposed into a number of sub-task. By providing this functionalities and the ability to plan, schedule and automate the negotiation process, the system has the potential to offer more complex services in which the users can express their needs as a higher-level goal.

CONCLUSION

Although advances in computer technology have greatly facilitated the use of CPM and PERT, the fundamental concepts employed by these planning tools for project planning are inadequate. Basically, these tools carry out computations on data provided by a human expert. Hence, they are unable to generate project plans and schedules nor able to update them intelligently in light of actual project progress. This paper has reviewed developments in construction material SC and highlighted the major deficiencies in current planning and scheduling procedures. One of this is inefficiency in planning (task decomposition) and scheduling (negotiation) processes. The paper has proposed the use of multi-agent systems (MAS) to overcome these deficiencies. MAS offer the potential to improve the efficiency of the SC processes by automating aspects such as the negotiation process and re-planning such that distributed participants can reach agreement quickly and proactively to changes that occur on the SC. The potential benefits of the proposed approach, which has being encapsulated in a door assembly application, have also been outlined. It is evident that the agent-based approach offers new possibilities for the efficient conduct of material procurement in construction projects. In an environment like construction supply chain, the ability of agents to autonomously plan and pursue their actions and goals, co-operate, co-ordinate, negotiate with others, and to respond flexibly and intelligently to dynamic and unpredictable situations will lead to significant improvement in the quality of the decision making output of the entire industry. This paper argues that the multi-agent system has the potential to improve the automation of the SC processes and also improve the fairness among the negotiating participants.

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THE ROLE OF TECHNOLOGY TRANSFER IN INNOVATION WITHIN SMALL CONSTRUCTION FIRMS

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ABSTRACT

Findings will drawn from an eighteen month research project involving in-depth case study and action research fieldwork with seven small construction companies to understand the role and significance of innovation for them.

A key finding of the work has been the importance of the role of effective technology transfer in the innovation process. An 'organisational factors of innovation' model is presented as an analytical and prescriptive tool to assist small construction firms to better understand and manage the technology transfer process. The utility and application of the model is illustrated with a case study.

KEY WORDS Technology transfer, Innovation, Small construction firms

INTRODUCTION

Technology transfer is widely considered to be a potentially powerful source of innovation which can provide construction firms with new technologies that can, where appropriate, transform and complement current technologies to create and sustain better levels of performance (for example, see Sexton *et al.*, 1999; Nonaka & Takeuchi, 1995; Kogut & Zander, 1992). Technology transfer is viewed as the movement of knowledge and technology via some channel from one individual or firm to another (for example, see Inkpen & Dinur, 1998; Gibson & Smilor, 1991; Devine *et al.*, 1987). Further, we take a broad view of technology, defining it as the know-how about the transformation of operational technologies and processes; material technologies; and knowledge technologies (for example, see Wilson, 1986; Hickson *et al.*, 1969).

The construction industry delivers its product to its client base by way of a stream of generally single and unique projects. These projects typically draw together a significant number of diverse small and large construction firms into varying collaborations (for example, see Betts & Wood-Harper, 1994). The ambition to bring about the kind of step change improvements in construction industry performance called for by the 'Egan' report (amongst others) must, by necessity, appropriately envision and engage large *and* small construction firms. Further, the scale of small firm activity in the UK construction industry is considerable, with, in 1999, ninety-nine percent of UK construction firms having one to fifty-nine staff (DETR, 2000: Table 3.1), delivering some fifty-two percent of the industry's workload in monetary terms (DETR, 2000: Table 3.3.) Therefore any overall performance improvement of the industry through technology transfer is significantly influenced by the ability of small construction firms to absorb and use new technology.

The role of technology transfer in innovation in construction firms in general, and small firms in particular, is poorly understood, and there is a clear need to rectify this (for example, see Atkin, 1999; CRISP, 1999). The aim of this paper is to contribute to this under developed area of innovation in small construction firms by offering new theoretical and practical insights and models coming out of an eighteen-month EPSRC IMI 'Innovation in Small Construction Firms' (ISCF) project. The structure of this paper is as follows. First, key issues from the technology transfer literature will be presented. Second, the aims and the research methodology of the ISCF project will be briefly described. Third, key findings from this project will be presented. Finally, conclusions and implications will be drawn, and in so doing, offer a more detailed understanding of the role of technology transfer in innovation in small construction firms.

KEY ISSUES FROM THE LITERATURE

Performance improvement based on technology absorbed into construction firms through technology transfer can and does occur successfully. Firms, however, need to understand and manage technology transfer activity to ensure consistent success. Sung and Gibson (2000) identified the following variables as affecting the degree of success in the process and results of technology transfer: person-to-person contacts; knowing whom to contact; variety of communication channels; set up transfer office or committee; a sense of common purpose; understanding of the nature of the business; attitude and values; increase in awareness of transfer; concreteness of knowledge/technology; establishment of a collaborative research program; clear definition of transfer; provision of incentives for transfer and product champions. However, present construction industry technology transfer endeavours are being severely hampered by a lack of proper understanding of such technology transfer issues and their interrelationships to both company capabilities and processes, and the knowledge characteristics of the technologies being transferred; in particular (Barrett & Sexton, 1999):

- First, current approaches tend to view technology transfer as a mechanistic 'pick-and-mix' exercise – identifying new technologies, and trying to insert them in their existing form into (unsurprisingly) unreceptive construction firms.

- Second, current technology transfer mechanisms are not sufficiently informed by, or engage with, company strategic direction and organisational capabilities and processes necessary to enable them to absorb technologies and to turn them into appropriate innovations. Experience from the manufacturing sector, for example, has stressed that the capacity of companies to understand and effectively use new technologies from external sources is heavily influenced by the level of prior-related knowledge and expertise (for example, see Adler & Shenhar, 1993).

- Finally, current technology transfer mechanisms do not fully appreciate that both the ability and motivation for construction firms to absorb and use new technologies is significantly influenced by the knowledge characteristics of the technologies. 'Hard' technologies which are characterised by explicit knowledge require very different diffusion mechanisms and organisational capabilities and processes than those required for 'soft' technologies which are tacit in nature.

The implications of these barriers for technology transfer in small construction firms crystallises the systemic nature of technology transfer, and can be fruitfully viewed, as shown in Figure 1, as a 'technology transfer system' (Sexton *et al.*, 1999):

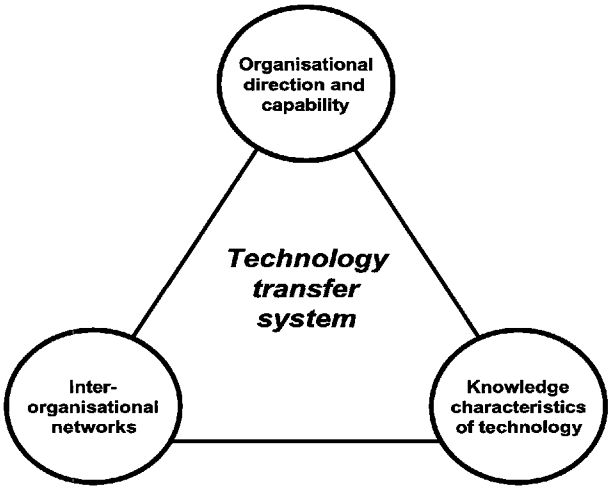

Figure 1: The technology transfer system

- Organisational direction and capability – the motivation and ability of small construction firms to absorb and innovate from new technologies has to come from within the firm; through envisioning technology strategies and supporting organisational capabilities.

- Inter-organisational networks – small construction firms, along with all firms, do not operate in a vacuum; rather, they are situated in a number of fluctuating inter-organisational networks of varying complexity. Inter-organisational networks promote and facilitate the development and transfer of knowledge and resources needed to encourage learning and innovation in participating firms.

- Knowledge characteristics of technology – the extent to which new technology can be effectively absorbed by small construction firms is substantially influenced by the characteristics of the technology being transferred. Two characteristics are especially important. The first is the extent to which the knowledge embodied in the technology is explicit or tacit. Tacit knowledge is hard to formalise, making it difficult to communicate or share with others. Tacit knowledge involves intangible factors embedded in personal beliefs, experiences and values. Explicit knowledge is systematic and easily communicated in the form of hard data or codified procedures. The second characteristic is complexity. Whether based on explicit or tacit knowledge, some technologies are just more complex than others. The more complex a technology, the more difficult it is to unravel.

The argument is that technology transfer will only be effective if all three elements - strategic direction and capability, inter-organisational networks and the knowledge characteristics of technology - are appropriately focussed and integrated to achieve a specific aim.

In summary, the literature stresses the important role of technology transfer in successful innovation and offers prescriptive guidance on how to manage the technology transfer process activity. Research within the construction industry, however, indicates significant barriers to effective technology transfer.

Results from the Innovation in Small Construction Firms (ISCF) project provide insights into the nature of technology transfer in small construction firms. Before presenting these results, the aims and research methodology of the ISCF project will be briefly detailed in the next section.

ISCF PROJECT AIMS AND RESEARCH METHODOLOGY

This paper is based on results from an eighteen-month project looking at innovation in small construction firms. The key aims of the project were to:

- Determine what innovation meant for small construction firms, particularly with respect to what is the motivation to innovate; and what constitutes appropriate innovation.

- Investigate how small construction firms create, manage and exploit innovation.

The seven collaborating small firms consisted of four consultants and three contractors. Firm size varied from eleven to twenty-six staff, and the turnovers (in 1999) ranged from £0.44m to £3.2m. The overall research process used in the ISCF project is given in Figure 2 (see http:www.scpm.salford.ac.uk/pbarrett for fuller discussion).

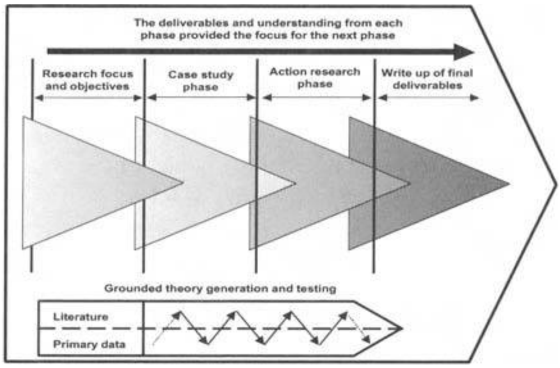

Figure 2: ISCF Research methodology

KEY ISCF PROJECT RESULTS

Definition of appropriate innovation

The ISCF findings defined *appropriate innovation* as:

> *the effective generation and implementation of a new idea, which enhances overall organisational performance*

This definition contains the following assumptions:

1. *Idea* – ideas are taken to mean the starting point for innovation. Ideas can be administrative and technical in nature.

2. *New* - not all ideas are recognised as innovations and it is accepted that newness is a key distinguishing feature. The idea only has to be new to a given firm, rather than new to the 'world'. Further, the newness aspect differentiates innovation from change. All innovation implies change, but not all change involves innovation.

3. *Effective generation and implementation* – innovation requires not only the generation of an idea (or transfer of a 'new' idea from outside the firm), but also its successful implementation. The implementation aspect differentiates innovation from invention.

4. *Overall organisational performance* – innovation must improve organisational performance, either individually, or collectively through the supply chain. Innovations that improve some isolated aspect at the expense of overall performance are undesirable.

'Organisational factors of innovation' model

The key implication of the ISCF definition of innovation for technology transfer for small construction firms is that they need the organisational capability and an appropriate response to the interaction environment to absorb and use appropriate new technologies. The ISCF findings produced a model of the organisational factors critical to successful innovation (see Figure 3) which proved to be useful in both understanding and managing innovation activity i.e. it is both an analytical and prescriptive model. The variables which make up the model are defined as follows:

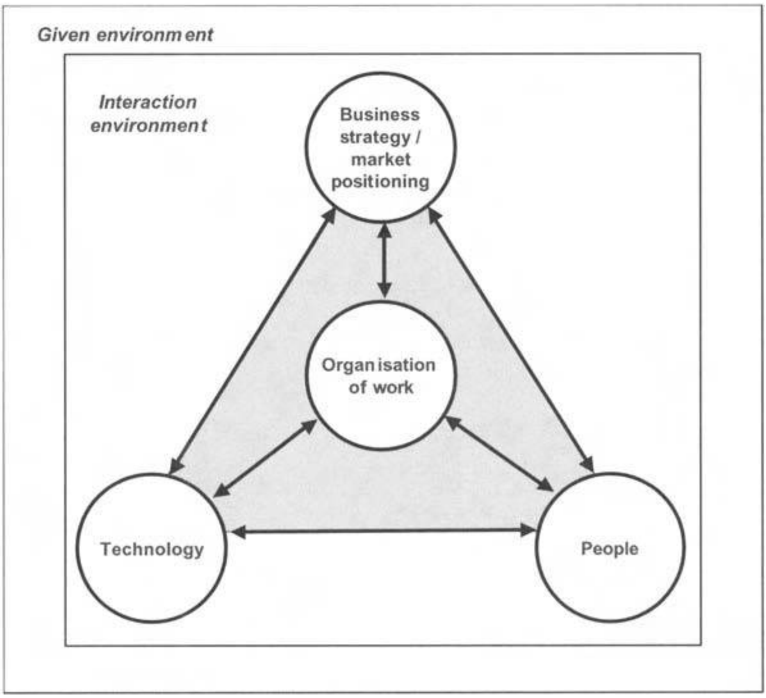

Figure 3.: Organisational factors of innovation model

- *Business strategy* is concerned with the overall purpose and longer term direction of the firm and its financial viability.

- *Market positioning* is the chosen (or emergent) orientation towards desired target markets for the purpose of achieving sustainable profitability.

- *Technology* is the machines, tools and work routines used to transform material and information inputs (for example, labour, raw materials, components, capital) into outputs (for example, products and services).

- *People* are viewed as possessing knowledge, skills and motivation to perform a variety of tasks required to do the work of the firm.

- *Organisation of work* involves the creation and co-ordination of project teams and commercial networks both within the firm and across its business partners.

- *Interaction environment* is that part of the business environment which firms can interact with and influence.

- *Given environment* is that part of the business environment which firms are influenced by, but which they cannot influence themselves.

The model proposes that business strategy / market positioning, organisation of work, technology, and people are the key organisational variables in understanding and improving innovation in small construction firms. The model emphasises and embraces both the holistic and systemic dimensions of innovation. The creation, management and exploitation of innovation involves consideration of not only the *content* of a chosen innovation, but also the management of the *process* of innovation and the *context* in which it occurs. The model considers two aspects of context: the inner and outer contexts of the firm. The inner context refers to the business strategy / market positioning, organisation of work, technology and people. The outer context refers to the given and interaction business environments. The process of innovation refers to the actions, reactions and interactions of, and between, the various organisational variables in the outer and inner contexts.

The utility of the 'organisational factors of innovation' model for understanding and managing technology transfer will be discussed by drawing upon a case study of one of the ISCF project collaborating firms.

Case study of technology transfer

The case study describes Consultant B's absorption and use of an off-the-shelf computerized quantity surveying system. Consultant B is a quantity surveying and construction cost consultancy with a turnover of £0.44 million in 1999. The firm has two partners and eleven staff. The case study will be structured around the 'organisational factors of innovation' model.

Given / interaction business environment

The ISCF project findings identifies clients as being the driving influence in the interaction environment. In common with all of the collaborating firms, Consultant B emphasised that:

"our strategy is very much driven from the outside by clients ... it is difficult for a practice our size to be proactive."

This was the case with the trigger to adopt and use the new computerised quantity surveying system, with it being stressed that:

"our clients initially drove it ... ten or twelve years ago we were working for [a UK water utility] and they insisted that all their bills be produced on a particular package."

Business strategy / market positioning

The ISCF project findings suggest that owners of small construction firms view the increasing investment in information technology as an area of significant innovation activity in itself, and as a powerful enabler for innovation in enhancing the quality and efficiency of the services their firms offer. Consultant B believed that it needed to invest in specialist software to enable them to compete with its competitors. Having measured a job, the firm wanted to be able to produce a more flexible document:

"We wanted something that we could adapt and alter slightly, because, although it is based on a standard library, which is based on the standard method and measurement, which is the time-honoured way of producing a bill of quantities, the industry wanted things quicker, and we needed something that would allow us to make 'short-cuts' and wouldn't keep us in a 'straightjacket.' We've just done a job for which one document was required for three different buildings. Basically once you've got one, it's very quick to do the other two. Much quicker that it would have been before; it is more efficient."

A further critical consideration in this sifting and evaluation process is the financial implications of a given technology transfer issue. The financial constraints faced by small construction firms affect the general capacity and capability for innovation. A partner of Consultant B argues that:

"small firms have a tight budget, so they don't have the people around to tackle a specific problem ... the cost of innovation is the short-term human involvement, and then having committed the capital to physically spend, you need some human time to make it work. The three go together. The big one though is the cash one."

This significant barrier to innovation is evident in Consultant's B future thinking for the computerised QS system:

"... we B would like to digitise its QS system, enabling staff to quicken the speed at which they measure external areas of buildings. However, the idea is considered too expensive and would need guaranteed work to make it worthwhile."

The key argument being presented here is that owners of small construction firms need to be confident of the business benefit of absorbing and using a new technology before they will commit significant resources.

In summary, the business strategy / market positioning dimension to technology transfer is very much centred around an informal, intuitive process of identifying business needs and carrying out cost benefit analyses to determine optimal solutions. The owners are close enough to their firms' markets and capabilities to instinctively know what will work and what will not.

Technology

The computerised quantity surveying system chosen by Consultant B was a proven off-the-shelf solution. This was emphasised in the observation that:

"At the end of the day, it's a system that any QS could buy; it's not something that's specific to us."

One of the partners of Consultant B stressed that although the software was, in itself, a piece of explicit, off-the-shelf technology, a significant amount of tacit knowledge had to be developed and shared before the technology could be absorbed into the firm and used. Indeed, it is acknowledged that "we are fortunate, in may ways, that we have one guy who works here who lives and breathes computers" and that:

"it is a fair comment to say that much of the knowledge needed [to use the software] is in people's heads ... I think that what happens is that if someone notices that if you press Alt-B this happens, then the word gets around; but apart from that no, there's no conscious decision to disseminate the information."

In summary, small construction firms often lack the organisational capability and capacity to readily absorb and use technology requiring a high degree of tacit knowledge. Small construction firms focus on 'consumable' technology which can quickly and more easily be absorbed into the organisation by informal, mini-experimentation through 'learning-by-doing.'

Organisation of the work

The organisation of the technology transfer process involved Consultant B developing a relationship with the supplier of the quantity surveying software and the users of the software, i.e. the firm's staff.

The supplier relationship provided Consultant B with access to the technical expertise of the software house, and the experience of other firms using the package. The benefits and nature of this relationship were described as follows:

"One of the benefits of the package is the support from the software people, so that if we say this didn't work well, or it would be handy to have this in here, they will look at it. They have workshops with various practices from around the country who use it."

The staff engaged in the technology transfer process at the piloting stage to ensure that the technology met the needs of the business and to nurture widespread ownership of the adoption of the new technology. The purpose and aim of the piloting stage was described as follows:

"The job on which we trailed the packages was a very, very simple job, a little bungalow .... I think it enabled us to choose the system; it showed us that (a) it worked, and (b) people were happy to use it, didn't find it too confusing and difficult."

The 'organisation of work' aspect, then focused on developing supplier and external users' network to access expertise and experience, and to combine this with the recipient firm's own capabilities. The combining of network and firm knowledge was facilitated through internal piloting to enable safe mini-experimentation and staff empowerment of the new technology.

People

The staff of Consultant B needed the knowledge, skills and motivation to properly use the quantity surveying software. The knowledge and skills was developed in two ways. First, the software supplier provided three training days as part of the package. Second, as described in the 'technology' section above, staff consolidated and developed their knowledge and skills through informal 'learning by doing.'

The ability of staff to use the new technology was not sufficient in itself; staff also had to be motivated to use it. This 'managing people through change' aspect was considered as core to the final success of the technology transfer. This imperative was captured in the following observation by one of the partners:

"I think we took people along with us when we were looking at it and making decisions; we didn't impose it. So people understood what we were trying to do and where we were trying to go. I don't think there was any doubt that we were going to do it. But because we wanted to keep the staff – we'd invested a lot of time and money in them – we wanted to take them along with us, and make sure they were happy."

In summary, the 'people' factor of innovation centres on developing the capability of staff to use new technologies. This principally takes the form of incoming expertise and experience from supplier and external users' networks (see 'organisation of work' section) and 'learning-by-doing.' The motivation of staff to adopt new technology is important, with appropriate engagement and communication to effective manage staff through change required.

CONCLUSIONS AND RECOMMENDATIONS

The ISCF results reveal that small construction firms absorb and use technology which can contribute to the business in a quick, tangible fashion, and which can be dovetailed into organisational capabilities they already possess, or which can be readily acquired or 'borrowed' through their supplier and business networks. Any technology which is too far removed from this 'comfort zone', and which requires too much investment and contains too much risk, tends to be intuitively and swiftly sifted out. A safe evolution approach to innovation through technology transfer is taken as the way forward, not risky revolution.

These results have implications for policy-makers and small construction firms. Policy-makers need to understand the differing ability and motivation of small construction firms to absorb and use new technologies compared to large construction firms. Further effort by government bodies and professional institutions is needed to filter and package well proven technologies that would appeal to small construction firms (for example, see Sexton *et al.*, 1999). For small construction firms, the 'organisational factors of innovation' model assists in identifying the factors critical to successful innovation through technology transfer: 'business strategy / market positioning', 'organisation of work', 'technology' and 'people.' The model provides a framework or checklist to help owner(s) identify what action has to be taken to progress an innovation in a systemic, integrated way.

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Simulation Concept of a Project Management Company

Jyri Sutt and Irene Lill

ABSTRACT

The model of production-economic performance of a firm is presented in current paper. This offered conception suits the best for companies whose production could be described as projects. It is based on the decomposition of a management system into management objects and management outlines. The goal functions, restrictions and planning techniques are appointed for management and production objects (buildings under construction), for resource subsystems of a construction firm (labour, machinery, finances etc) and for economical processes (task of profit planning in long-range). Management outlines are determined from one side by administrative and planning outline, stated by planning systems (goals, organisational-technological restrictions and planning rules) and from the other side by regulations outline, describing economic system, which has to motivate its elements through economic norms to take favourable decisions for the system. The adequacy of the model makes it possible to use the simulation system as for improving the management systems (planning rules, regulation programmes, and economic norms) as for compiling and evaluating the operative production plans.

INTRODUCTION

The efficiency evaluation of economic subjects' behaviour on the market from profit generation viewpoint is a target of microeconomics theory. Applying the microeconomics theory to construction sector is possible only after defining the basics: what is construction market, who is demander and who is supplier, what do we mean by product and how we could measure the productivity. In construction market the owner consuming construction products or services is always one partner. The uniqueness of construction industry compared to mass-production is that building production can be described as projects. Construction projects are large-scaled, complicated and time-consuming. That is why the owners have to deal at least with three different markets depending on the progress of particular project. At first, the real estate markets, where development projects are considered as products and completed buildings and expenses during their whole life cycle are taken into account. Secondly, market of construction design services, where cost of design is dominating but construction cost must be controlled. And thirdly, construction market, where products are buildings and only construction costs are taken into account. Construction firms appear in a role of demander and a project involves only its construction period. Current paper deals exactly with the last mentioned category – construction market and its modelling problems.

Construction market is treated like in traditional microeconomics. Behaviour of market partners is expressed by demand-supply curves and production functions, where price, costs and productivity appear as variables. At the same time simplified models let us search for explanations to the behaviour of construction firms and not only find the reasons but give some quantitative assessments also to the gains and losses caused by different economic decisions or management strategies.

PROBLEMS IN CONSTRUCTION MARKET

During the period after Second World War the weight of traditional contracting procurement method has been decreasing leaving professional construction management as procurement method more space of growing. In latter case the project management company appears clearly as owner's partner. Even more, the last decades show the tendency of lessening the amount of works accomplished by main contractor up to passing all the work over to subcontractors. In mentioned situation only the main contractor fulfils a project management function. Our attention is concentrated mainly on the main contracting method as it is still the ruling form of contracts used in practice.

There are two main reasons which cause mentioned above changes. At first, the main contractor trying to complete the majority of construction works with its own labour has to face the unproductive expenses connected with uneven working load on the buildings under construction but also irregular orders portfolio. Releasing the workers is one way to reduce these unproductive expenses. The second reason is connected with the owner. In laissez-faire construction market (the construction price is already stated in advance on a large scale as the result of design process) the owner's revenue is depending on construction duration: expected profit from the profitable object under construction and saving of loan interest. That's why owners are continuously pushing contractors to shorten the length of construction period, which in turn extends the problem of unrhythmic working load. This problem is described in Figure 1, where four projects are carried out in two different ways. To compare the results and to exclude the effect of scale the total amount of work in both cases is equal.

The described above trend in construction market and its reasons are pretty obvious, but we can't ignore the negative consequences of abandoning workers by construction firm. Eventually while assigning works to subcontractors the main contractor is giving up part of its potential profit. Are the expected profit and potential losses comparable? Even more critical is ignoring workers' training and qualification responsibilities. In long-term it will lead to abatement of workers' qualification with accompanying influence on the quality of construction works, as only larger companies are able to provide high-level professional training (Mackenzie *et al.*, 2000).

DIFFICULTIES IN REFLECTING CONSTRUCTION MARKET

We have to set some restrictions to current problem approach in purpose to get answers to raised questions. The profit formation of a building company can be described by three management outlines: project management, resource management and process management.

Project management subsystems include project and site managers and their teams.

Resource management subsystems are dealing with workforce, machinery, materials and finances. The prevailing goal of project management subsystem is to maximise the revenue while for a resource management subsystem it is to minimise the operative costs. As a rule enhancing effectiveness of project management (shortening construction time) in construction firm brings along the raise of operating costs of resources. In contrary, decrease of resources' operating costs will lead to prolonging of construction time.

And finally, the process management subsystem, which has to balance the often non-coinciding interests of above mentioned subsystems. The goal of the subsystem is to maximise the profit of a firm in long-term perspective. The problem of main contractor can be described as multi-project planning in conditions of limited resources.

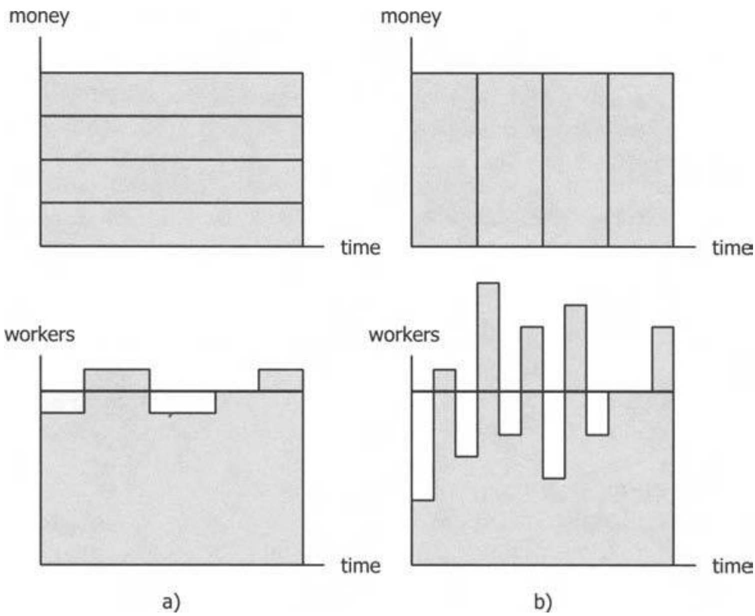

Figure 1 Two opposite project management strategies

Described upper trends in construction market indicate that economic results of construction company depend more strongly today on efficiency of project management than on resource saving. That is the reason why our main attention is paid to the ability of management strategies to influence construction firm's profit, ignoring at the same time the price the firm managed to pay buying its resources and determining mark-up. Otherworldly, the latter is observed independently from project management strategies.

We need to determine the measure unit for productivity in purpose to carry out the quantitative analysis of the problem. It is impossible to use the number of completed buildings in months or year as it is done in industry microeconomics. That is the reason why model of traditional microeconomics and firm theory are not applicable for description of construction market. Buildings under construction could be described as projects and the intensity of fulfilling the projects (productivity) could be measured through the length of construction period. As the length of construction period but also the buildings under construction themselves are very different we have to use relative duration as measure unit. The benchmark for relative length of construction period could be technological minimum construction duration in one-shift working schedule T_{1S}^{min}. Technological minimum construction duration means that maximum of resources (works, cranes etc) are involved on the works of current project. The normative (statistical) construction duration could be also considered as benchmarks, if such exist. If we assign the construction duration of a particular project as T^F, the intensity of works could be expressed as ratio T^F/T_{1S}^{min}. The productivity of a main contractor annually performing works on numerous buildings could be expressed as average of named ratios or through weighted average of work quantities.

There are some theoretical boundaries that influence owner's and contractor's behaviour on the market. Owner's peak demand and revenue expectations respond to the minimum construction duration where works on critical path of a project are executed in three shifts – T_{3S}^{min}. Owner's interests are stated through maximising the productivity, which come together with shortening of construction time. This situation is explained in Figure 2, where one and the same building (areas of the rectangles are equal) has been completed in different intensities. The expected change of owner's revenue is proportional to $T_2 - T_1$ and change of retrenchment of financial expenses (loan interest) is proportional to $L_2 - L_1$.

From contractor's viewpoint a different term of interest exists – productivity meeting the theoretical minimum of unproductive costs spent on resources. This responds to relative average construction duration, providing the uniform working load for firm's labour force during the entire year as by buildings under construction as for the main contractor in a whole. Problem is reflected in Figures 3 and 4. Unproductive costs on labour forces caused by uneven working load are connected with additional payments (overtime outgoings, bonuses) proportional to overloaded man-shifts and downtime costs proportional to under loaded man shifts in multi-project calendar plan of a main contractor.

Dependence of unproductive costs on construction duration (productivity) could be also observed within a single building site (see Figure 4).

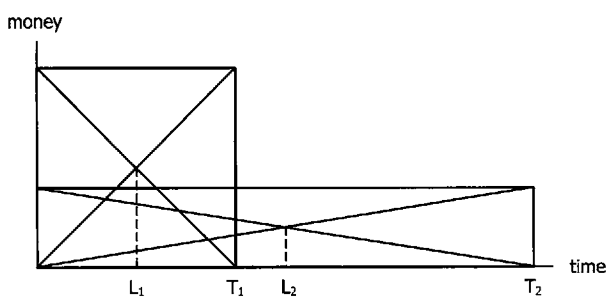

Figure 2 Dependence of owner's revenue and retrenchment of financial costs on construction time

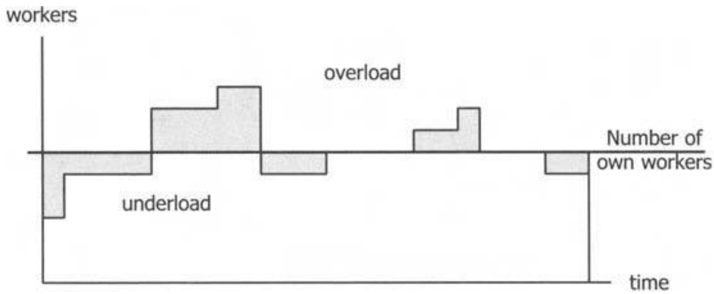

Figure 3 Loading problems of main contrctor's labour forces

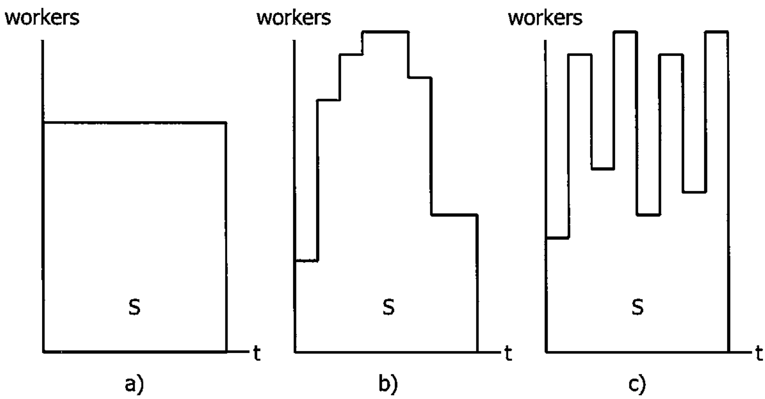

Figure 4 Workers switching from one building site to another

Changing the number of workers on every step corresponds to switching workers from one site to another. Every time worker has to change the building site he looses about half of his workday even if transferring takes place out of a working day. It is easy to prove that solution (a) is better than solution (b) and (b) is better than (c). At the same time (a) as a uniform working load is considered as theoretical limit. Experimental modelling of calendar plans shows that it is possible to achieve the uniform working load of labour and accordingly minimise these unproductive costs while average construction duration is $T^F = 2{,}5\ T_{1S}^{min}$. It is obvious that such a construction time which exceeds the normal length of construction period in multiple times raises interest only theoretically. The time schedule in microeconomic models of construction market could be illustrated as in Figure 5.

MANAGEMENT AND SIMULATION SYSTEM MODELS OF A CONSTRUCTION FIRM

Management subsystem of a construction firm involving three different management outlines is represented in Figure 6.

The upper part of current scheme reflects the management subsystems of buildings $B_1 \ldots B_n$, with the project manager at the head of every building site and according working staff. The goal of every single subsystem is to maximise its profit.

At the bottom the resource management subsystems are shown, the goal of each is recruiting / supplying with resources of proper quality of possibly minimal cost.

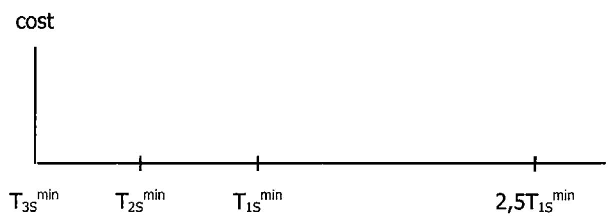

Figure 5 Productivity benchmarks (average relative construction duration) in construction market models

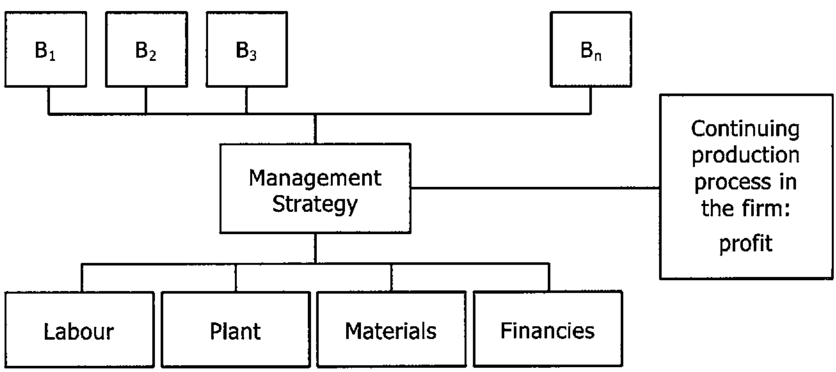

Figure 6 Model of a construction firm management system

On the right hand the management of production process which has to provide continuous profit generation for current firm is represented: marketing, multi-project calendar planning, financial book-keeping and its supporting functions as measurement of quantities, preparing new technologies etc.

From IT aspect using the information about buildings under construction (B) in form of technologic links and bills of quantities of works and resources from one side and from the other side information about the available resources in the firm (amount, quality, restrictions if any, productivity), it is possible to schedule a continuous production process.

Calendar plan stands as a model for the production process in construction business. Modelling of main contractor's activities in a shape of multi-project calendar plan isn't a problem by means of nowadays IT technology. The described simulation system generates a model of production process and is able to appraise it through external (credit interest, profit rate, fines for exceeding the deadlines etc) and internal (wages, bonuses, overtime payments, extra payments for evening and night-shifts and freezing conditions etc) norms reflecting this enterprise. In our approach the economic assessments of production process (cost price, profit) do not reflect the absolute values – but we can estimate the changes of cost price or profit under influence of altering the management strategy or economic norms.

On Figure 7 the principal structure of simulation model is represented which proceeds logically from the management model of a firm illustrated in Fig. 6.

Models of buildings are presented in form of networks, where every single task is described by its quantity, cost and its components: expenses on wages, materials and machinery, e.g. resource requirements in resource subsystems (see Fig. 6), where corresponding economic regulations are coming from (stimulating resource usage and evaluating the efficiency of their exploit). We are dealing with very detailed isomorphic model but taking into account the possibilities of modern IT technology in automation of budgeting and calendar planning creating of matching database isn't a problem any more. The topology of network schedules ensures that construction-technological restrictions will be taken into account for every building under construction.

Generator of construction situations (see Fig. 7) is using a program of multi-project calendar planning which is able to take into account limits on resources.

Model of construction process is a scheduled calendar plan of works carried out in firm in shape of matrix-structure, where time intervals appear in columns and the intensity values of needed resources for every work are matrix elements.

Taking into account that in simulation modelling the simplification is unavoidable and in purpose to assure the adequacy of model of construction process to reality it is reasonable to suggest that a professional takes interactive part in process of modelling (see feedback lines in Figure 7).

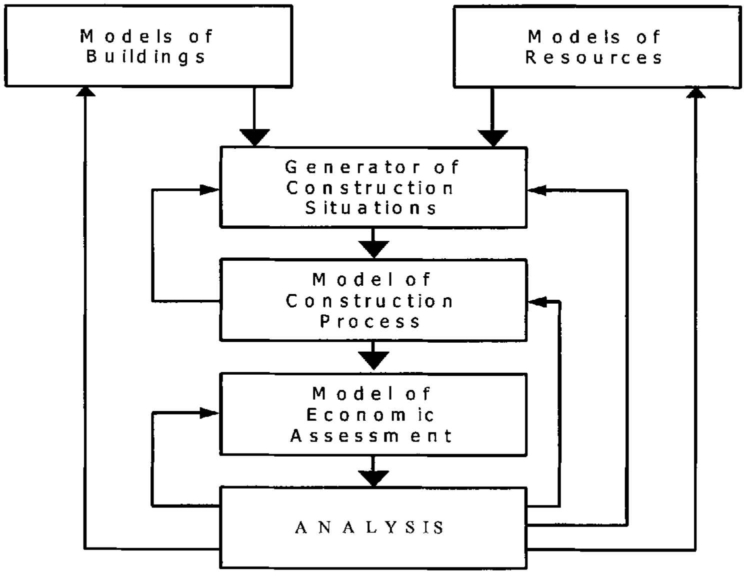

Figure 7 Principle structure of the simulation system

MODEL OF ECONOMIC ASSESSMENT

Factors influencing construction cost price

We can predict that there are components of cost price, which are going to change depending from productivity (average construction duration). Components, which could be measured by means of described simulation system, are represented below. The changes of observed cost price component C are given in percentage towards the most favourable cost price level from firm's viewpoint, which is provisionally equalised to zero. This means that we are comparing different resource costs with the most resource-saving level of expenditures.

The components reflecting changes in labour costs are linked with the uniformity of uneven working load as explained earlier (see Fig. 3 and Fig. 4) and are caused by:

- slack time
- overloading
- switching workers from one building site to another

All three mentioned components are measured separately in the simulation system. Their total influence towards the construction cost price is shown in Figure 8. The costs on labour rise by 2,5% while shortening the construction duration from the most favourable (uniform) loading solution which is achieved at 2,5 T_{1S}^{min} down to the theoretical minimum length of construction period at T_{3S}^{min}.

Above that, usage of labour brings along additional costs while shortening construction duration by arranging works in evening and night-shifts (loss of time while passing work over between shifts, productivity slowdown at night-time, extra payments). Working in 3 shifts increases firm's expenditures by 2%. Dependence between these costs and construction time has nonlinear shape, because shortening the construction time pushes more and more works on critical path and this isn't a straight-line process (see Figure 9.) The changes of overheads have also been taken into account as decrease of productivity brings along the increase of fixed part of overheads on production unit weight.

There are two components depending on the average construction time concerning costs on construction machinery. At first, expenses on transport, mounting and dismantling of building machines (e.g. tower cranes). It is possible to give this a simple explanation with the help of Fig. 1. While in case (a) we presume that 1 crane is needed on single building site, then for case (b) we need 4 cranes. The number of overgoings will grow accordingly from 4 to 16. In both cases the total amount of machine-shifts is considered to be equal. The changes of according costs are shown in Figure 10.

Other running costs of construction machinery do not depend on the average construction duration if working in one shift. But working in 2 and 3 shifts the costs of machinery per work unit decrease as one machine can serve more workers (Figure 11).

The same way we can describe dependence of some more components of cost price on construction time:

- Costs of temporary buildings and works: more concentration of works in time unit – more costs

- Costs of accessory works (clearing the building site and streets, traffic costs etc), which are reflected by construction duration in opposite way than previous component.

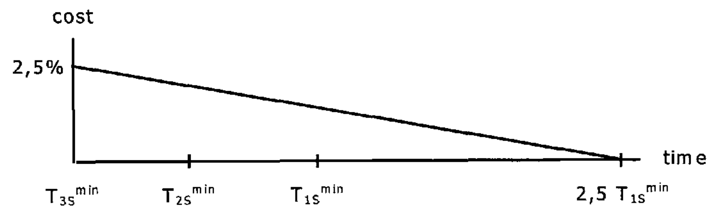

Figure 8 Dependence of labour costs on uneven working load

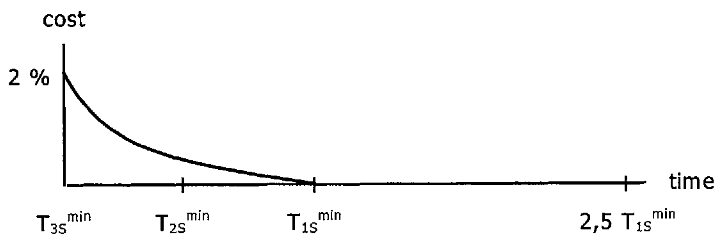

Figure 9 Changes of additional costs on wages and overheads depending on number of shifts

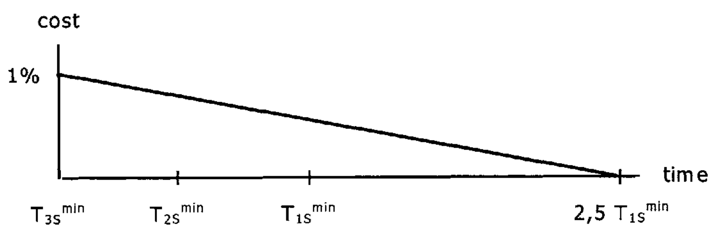

Figure 10 Costs on overgoings of machinery.

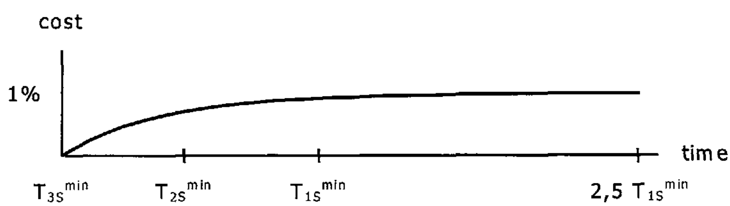

Figure 11 Current costs on machinery.

As their influence is approximately equal in investigated time interval we can ignore their influence.

- Costs of materials do not depend on average construction duration except procurement and storage costs, which are growing because of decrease of productivity in 2^{nd} and 3^{rd} shifts. The quantitative influence of mentioned component has been already taken into account in cost curve in Fig. 9.

- During the simulation experiment the dependence of financial costs was also investigated: shortening of construction duration brings along the raise of risk, which demands higher supplies and means that there is a need in additional current assets. It appeared that influence of mentioned component was statistically insignificant.

We have to summarise all these described functions while studying the behaviour of construction firm. The total changes of cost price are presented by curve C on Figure 13. We are ignoring the construction duration in interval $T_{1S}^{min} - 2,5T_{1S}^{min}$ as practically unimportant as cost changes there are less than 1%.

Factors influencing owner's revenue

The owner's interests in productivity of construction market have been explained with the help of Fig. 2. The results of simulation experiment are shown in Figure 12 as components of owners revenue curves, which express the according distribution of profit (R_1) and increase of interest charges (R_2) compared to the most profitable planning solution, where technological minimum construction duration was achieved and works were scheduled in 3 shifts.

Equilibrium Condition of Firm

Could there exist an average construction duration satisfying both: as contractor as owner? Looking for answers we had to study together the owner's revenue function $R=R_1+R_2$ (see Fig.12) and curve of contractor's total costs C linking them together in Figure 13.

Owner's revenue (R) could be interpreted as curve of demand, which is oriented to supplier. In purpose to make costs and profit comparable is curve R turned around in relation to Fig. 12. The analogy with traditional microeconomics of industry could be found in total revenue – total cost approach.

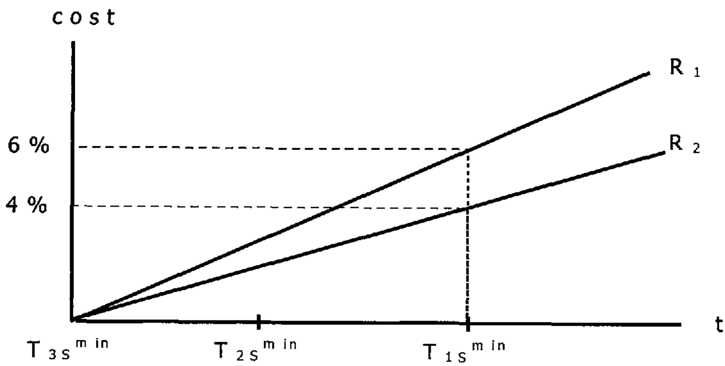

Figure 12 Dependence of owner's revenue function

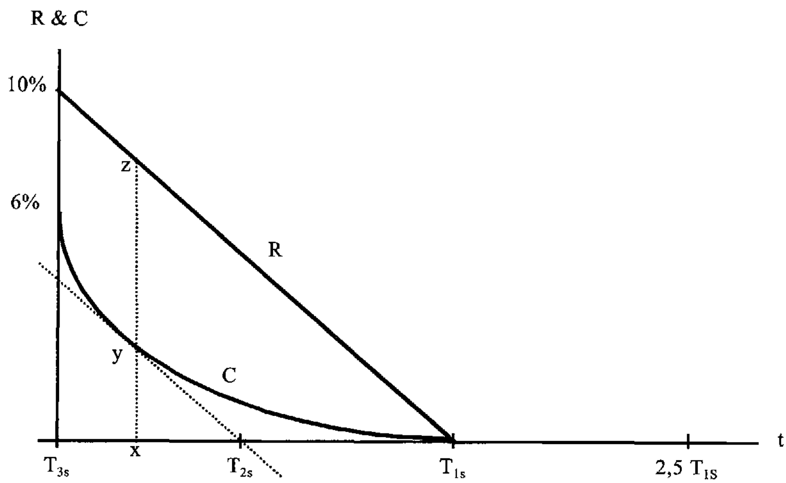

Figure 13 Summary functions of contractor's costs (C) and owner's revenue (R).

In case of present example (the result of simulation experiment) the costs of construction firm increase by 6% compared to the most favourable solution. It is clear that the respective costs must be reflected in the construction price. If the respective growth of owner's summary revenue R is higher than C, then there are both: means and interest. In our example R corresponds to discount rate 10%. We discover the most favourable construction duration if we find a tangent to the curve of costs C, which is parallel to the curve of profits R. If (x-z) (Fig. 13) shows the potential increase of the owner's total profit from shortening of construction duration, then the owner must give up (x-y) to compensate the constructor's supplementary costs. To escalate the contractor's interest in shortening of duration the owner should give up part of the remaining profit (y-z) to incentive the contractor. In cases the profit function is linear and cost function non-linear the most effective stimulation is dividing the profit 50:50 (Groves, 1973).

INTERPRETATION OF SIMULATION EXPERIMENTS

Quantitative assessments of profit and cost functions described above are based on the experiment, where production performance and economical activities of an average main contracting firm was simulated during a two-year working period. Company was executing works on 18 different buildings, which construction duration in one shift schedule varied from 6 to 18 months. There were 200 workers in the company and 50% of works were carried out by its own labour, while finishing, sewage, electric and other special works were realised by subcontractors where we didn't set any resource restrictions. The average construction duration was systematically changed during the simulation experiment from T_{3S}^{min} to $2,5T_{1S}^{min}$.

The experiments showed that the length of construction period is an important factor in construction price formation and it has to be taken into account in demand and bidding (supply) phase. These dependencies have to be recognised as by clients as by contractors.

We raised a question at the beginning of current paper: If the tendency where main contractors are abandoning their own labour in purpose to avoid costs caused by uneven working load is reasonable? The answer could be: partially, yes. The increase of cost price from time interval T_{1S}^{min} to T_{3S}^{min} was 6% from which costs connected with uneven working load could be estimated as 3%. The main contractor discarding its own labour force (~ 50% of works in current example) is giving up also the according part of its profit. Presuming that profitability of construction firms is about 5% we can figure that the according loss would be about 5% x 50% e.g. 2,5 %, what is approximately equal to number gained as the result of revealed management strategies described above. And from here new logical question arises: What are the alternative management strategies to solve this problem?

One possible solution could be in using multi-skilled workers. The according simulation experiment was carried out in purpose to learn the efficiency of overlapping trades. Step by step the workers of main contractor (50% of all the works) were assigned to additional skills (carpenter – assembler – bricklayer – roof worker – concreter – glazier – plasterer – general labourer). The results of simulation experiment are shown in Figure 14, where n is number of overlapped skills.

We learned from the simulation experiment that multi-skilling decreases construction cost price through shortening of construction time as the result of better labour loading. We can bring out the following:

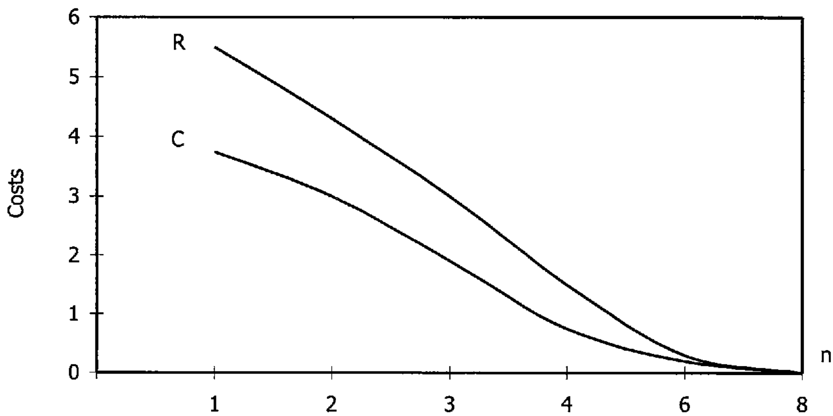

Figure 14 Dependence of contractor's cost price and client's revenue on number of combined trades

- using multi-skilled workers makes it possible to shorten the length of construction period by approximately 30% due to a more uniform and full working load for labour resources.

- overlapping four trades decreases the cost price around 3% and the growth of potential client's revenue about 4%. The influence of combining more than four skills is insignificant as is the effect of using different specific combinations of trades.

- it indicates that it would be worthwhile to pay workers for acquiring additional skills.

CONCLUSIONS

The presented conception which lies on the mutual modelling of owner's and contractor's economic interests let us to describe their behaviour on the market of construction projects, which couldn't be performed with the means of traditional microeconomic models of the firm theory because of peculiarity of construction as production branch.

The structure of the simulation system as a system of decomposed models let us use it for many other investigations of production-economic problems as on the market of construction projects as construction labour market, but also inside the firms while choosing the alternative management strategies. For example: while changing systematically the stimulation policy inside the firm we can observe its influence to company's profit; or influence of mechanisation (expenses on labour and machinery) on the profit; or the efficiency of different calendar planning algorithms etc

The simulation system described above and microeconomic models (production models) created on its basis are described in detail by Sutt (1985).

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Impact of Information on the Construction Industry

Authors: Dean T. Kashiwagi and John Savicky

ABSTRACT

The construction industry is composed of manufacturers, contractors, designers, inspectors, construction managers, and end users or facility owners. This article defines information as 'nonbiased data that accurately describes an entity in relative terms and predicts the future outcome'. It describes an information environment and explains how information that is generated by an artificial intelligent system will impact the construction industry. An information environment will include the relative performances of contractors, construction systems, and constructor personnel (project managers and site superintendents). This information will alter the functions of designers, constructors, and construction managers. This includes the minimization of subjectivity and decision making (minimum standards), the identification of performance and value, and the minimization of non-value added functions (inspection, designers directing contractors with means and methods, designers subjectively deciding what works and what does not, and the low bid awards which assumes that all contractor services are the same). For the past six years, PBSRG has been researching the impact of an information environment created by the Performance Information Procurement System (PIPS) and an artificial intelligent processor which generates performance information. This article will use test results from three different environments, the states of Utah, Hawaii, and Georgia, to show the impact of information systems on the future construction structure and environment. It identifies the new structure, the new roles of the major participants, and how the transition may be accomplished.

INTRODUCTION

Information is defined as data that predicts the future outcome, or differentiates two alternatives ability to accomplish a required outcome. In an information environment, risk (not accomplishing a future outcome on-time, within budget, and meeting quality expectations) is minimized. A high performance contractor will perform well; a poorly performing contractor will perform poorly. With information, the outcome will be easily predictable. Figure 1 shows a rate of change diagram with a two way Kashiwagi Solution Models (KSM). The Rate of

Change diagram shows that if there is a high level of perception of information, the other factors that also describe the environment include reduced project management by the owner (decisions, control, and inspection) high performance, lower contractor volume of construction, higher profits, and contractor responsibility and liability for the construction. Protests should be minimized due to the owner not making decisions. Also the matching up of owner and contractor by level of information and processing speed, minimize the amount of partnering required.

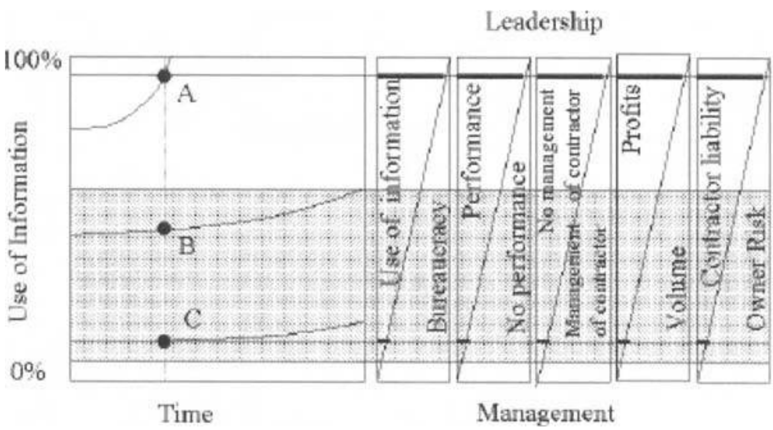

Figure 1 Rate of Change/KSM

The information requirement should lead to the following:

1. Identification of level of information and performance of the owner and the contractor.

2. Evaluation of risk to the owner and contractor by the contractor.

3. Fully open competition between contractors to meet expectations of the owner.

Deming states that the owner or user always identifies performance. Therefore the owner is responsible for communicating their level of performance to the construction community. If the communication is clear (information which contractors can perceive and understand) the performance will be higher. If the communication is unclear (confusing and lacking information) the performance level will be lower. Performance is the contractor delivering on-time, on-budget, and no contractor generated cost change orders.

Performance Information Procurement System (PIPS)

PIPS is an information based environment. PIPS forces the collection of data, the transformation of data into information, and the selection of best value. Because it is an information system it minimizes the need for management, partnering, and inspection. PIPS includes the following steps (Kashiwagi, 2001):

1. Identifies the performance of the contractors by collecting past performance data from contractor identified references. PIPS forces the contractors to identify the criteria and their best references. No minimum number of references are required, forcing the contractor to make the decision on which and how many references they submit. The contractors are told to only submit references that show their best performance.

2. Contractors are given a Request for Proposal (RFP) that can include full or partial design or requirements only).

3. Contractors attend a prebid meeting to listen to the expectations of the owner. Contractors are told that the owner will consider past performance (general contractor, key subcontractors, and personnel) ability to identify and minimize risk of the owner on the project (including detailed cost estimate, construction schedule) and price.

4. Contractors turn in a bid (management plan, price).

5. Owner rates the contractor's management plan and interview of key personnel to rate the ability to identify and minimize risk (not being on budget, on time, and meeting the owner's expectations).

6. Contractors are prioritized by an artificial intelligent processor (Zeleny, 1985) based on the contractors' past performance, ability to minimize risk, and price based on the owner's subjective requirement.

7. The top prioritized contractor reviews the project with the critical subcontractors, identifies items of constructability, optimized means and methods, or points needing further clarification. All requests for information are answered before the signing of the contract.

8. The contractor then signs a contract to construct the building according to the RFP, proposed management plan, and clarifications within budget, time, and meeting quality expectations. The contractor's performance on the project than becomes 25% of the future past performance barcode, which represents the contractor in any future procurements.

The process has three main filters: information environment, evaluation of risk, and competition based on performance and price (Figure 2). The first filter is the level of information of the owner. If the contractor does not match the owner's level, the contractor will withdraw due to a large variance in the level of information use. During this stage, the contractor learns who the owner is. The second filter is the contractor's ability to identify and minimize risk to the owner. This ability comes from past experience. The third filter is the competition between contractors based on price and performance. Once a contractor has prioritized the best value, the contractor is directed to coordinate the project with the critical subcontractors, identify areas needing clarification or change, and get the answers from the designer prior to the contract award. The contractor and their critical subcontractors are rated on their performance of the project. These three filters create an environment that is a left sided, or information environment in the KSMs. Once a contractor wins the project, they must perform and be rated.

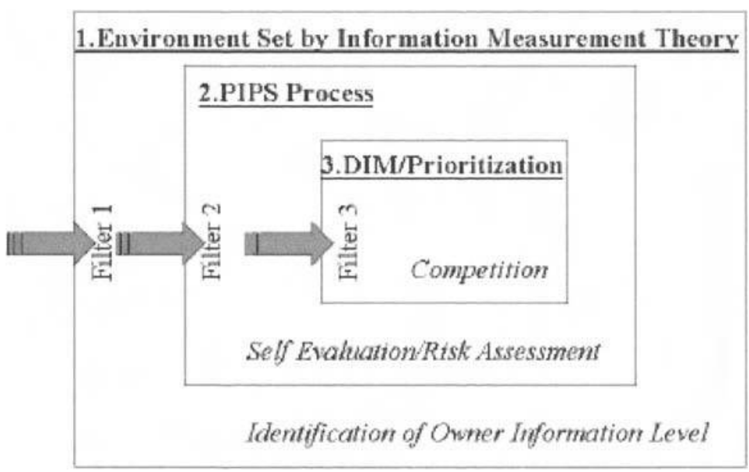

Figure 2 Information Filters

Decision making by parties is minimized in an information environment. The information filters will make the decisions. This includes minimization of the following by the owner:

1. Means and methods directions.
2. Minimum standards.
3. Project management.

4. Inspection.

Every contractor and manufacturer should be allowed to make decisions to describe their performance identity. This involves the following decisions:

1. Who their references are.

2. How many references.

3. Which are the good references to submit.

Figure 3 shows a contractor and their various construction teams. Contractors have highly trained groups (HT), medium trained groups (MT), and poorly trained groups (PT). If there are four owners, a performance based owner (PB), a longtime customer (LC), and low-bidding owners (LB), the most highly trained team is sent. This has been supported by over 300 tests. Therefore, the owner is only interested in the contractor's best performing references. This decision must be made by the contractor to identify themselves. If a contractor does not have HT or MT teams, the contractor will self eliminate themselves until they are better trained or until they can hire staff that is better trained. The information filters discourage nonperforming contractors until they are better performing.

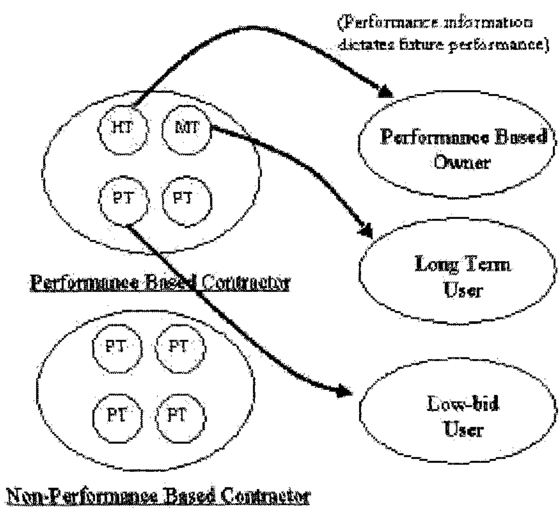

Figure 3 Contractors' Best Performance References

PIPS tests have resulted in the following practices:

1. Best contractors with their best people.

2. Self management.

3. Higher profits.

4. Minimized project management (control, direction, inspection).

PIPS results include:

1. 300 projects, $100M of construction.

2. Average owner rated performance: 9.5 (10 is highest).

3. 100% on budget, no contractor generated change orders.

New Information Based Construction Structure

The new construction structure affects the contractors, designers, engineers, consultants, and the owner's representatives. Information worker responsibilities include:

1. Owner's project manager: facilitate designers and contractors. Minimizes decision making except to rate the contractor at the end of the project. The project manager becomes a facilitator.

2. The designer identifies the requirements and the scope (owner's aesthetics, size, sitting, mechanical, and electrical, and code requirements).

3. The contractor takes control over the construction, takes responsibility for performance, and verifies, and maintains their performance line.

The following processes become non-value added functions in a construction performance information environment:

1. Owner's project management (inspection, control, scheduling, and direction).

2. Specification of means and methods, system properties, and punitive general conditions (liquidated damages, redone work, etc.).

3. Minimum standards, prequalification, long term partnering arrangements.

4. Leveraging volume to get a cheaper price.

The existence of the above practices identifies the low level of information in the construction industry. PIPS testing has identified that the problems identified in the construction industry can be minimized by using performance information. Designers must become information workers who can:

1. Minimize decision making.
2. Facilitate.
3. Identify value through the use of information.
4. Minimize risk.
5. Pass information and not data.
6. Minimizing the owner's decisions.
7. Optimizing the construction event that uses the best available contractor.

All procurement systems have a relative level of information. The following can identify the level of information:

1. Level of open and totally free competition.
2. Level of differentiation required by the process.
3. Level of disclosure of information to contractors.
4. Level of subjective decision making and control of the user.
5. Level of motivation to change that is measured by the performance received.
6. Level of understanding of IMT by core group of administrators and ability to become information workers and minimize decision making.
7. Period of continuation of information environment.
8. Contractor's improved performance (on-time, on-budget, and quality).

Results in Four States

PIPS was tested in four different states: Hawaii, Utah, Wyoming, and Georgia. The most successful implementation (based on the above identified eight factors) has been in the State of Hawaii. The State of Hawaii has been able to:

1. Run the process for three consecutive years.

2. Trained a core group which included the director, project administrator, program manager, and project manager levels.

3. Used the full information system including the artificial intelligent (AI) processor to replace human decision making.

4. Opened competition to all contractors. There was no prequalification.

5. Continually improved the openness of information environment.

6. Trained other staff to run process even though they were opposed to the process.

7. Posted all performance information and the results on the Internet with full access.

8. Reduced decision making and subjectivity. Minimized project management by 90%.

9. Strong construction industry support.

10. Opposition by designers to the change to an information environment.

The State of Utah ran the largest PIPS projects to date (6 projects, $80M of construction). The following are the results:

1. All six projects were finished on-time, on-budget, and met quality expectations. There have been no contractor generated cost change orders that have been identified. There have been scope changes and unforeseen conditions.

2. The construction projects have been the best construction results in the last ten years.

3. The State of Utah did not train a core group of information workers in the tests. The two drivers of PIPS, the facility manager and most successful project manager no longer work with the State due to disagreement of level of control instituted.

4. The State decided to attempt to modify the information system to a lower information level. Instead of using the AI processor, and the high level of information, they reduced the level of information to only the general contractor (instead of the critical craft subcontractors),

reduced the amount of data from 40 references verified to 5 references, and allowing the committee to make a subjective decision.

5. The performance information of the contractors and are not posted on the Internet.

The lack of access to performance information may minimize the prolonged success of a best value (performance and price) procurement system. The general trend when there is a lack of information is to go back to low price based awards. The State of Georgia has run two PIPS tests. The following are the results:

1. The first project was over-designed, and resulted in being awarded based on low-bid after a redesign using value engineered ideas from the performance based contractors. The project was still over-designed. An analysis of the information showed that the performance based lowest bidder was the best value. It showed that higher performing contractors do not necessarily cost more.

2. The second project was also over-designed. The project was awarded after redesign to the best performing contractor. The construction project manager and designer of the project were not educated in PIPS as well as the State of Hawaii project manager.

The State of Wyoming tested PIPS on roofing projects and the procurement of copy machine service. The tests resulted in performance construction and copy machine service. The State of Wyoming has moved toward a more subjective process.

CONCLUSION

The greater the level of information, the higher the performance of the contractors and the less management (up to 90% reduction) is required by the user. The impact of the performance is directly related to the minimization of control and the use of information. Information increases construction performance. Each owner must select the level of information that the environment will allow to be used. Each environment dictates a certain level of information. By definition, government agencies that are bureaucratic will have a difficult time using information systems. Implementation of true information systems are difficult to implement in governments due to the rule based, nonchanging, inability to differentiate, and use and pass information. Implementation in a government group requires finding 'information workers' at three levels, the executive, the management, and the project manager level. Without this team, tests in Hawaii, Wyoming, Utah, and Georgia show that it is very difficult to implement and use as information based procurement systems as a permanent process.

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Knowledge Management for Continuous Improvement in Project Organisations

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ABSTRACT

Project-based organisations operate in a dynamic business environment where those that do not have continuous improvement initiatives are unlikely to survive. Continuous improvement is based on an organisational capability approach underpinned by innovation, learning and competence based strategy. The Knowledge Management (KM) process is central to this approach as it offers an opportunity to improve the performance of future projects through organisational learning and innovation. This paper presents a framework for managing knowledge in construction project organisations and concludes with a strategy for identifying and applying knowledge of best practice for continuous improvement.

INTRODUCTION

Project-based organisations operate in a dynamic environment where it is becoming increasingly difficult to gain any competitive advantage without a structured approach to continuous improvement. Knowledge Management (KM) is central to this approach as it facilitates continuous improvement through project learning and innovation. Continuous improvement is achieved by applying 'knowledge of best practice' gained in previous projects in order to improve the performance of future projects. The drive for continuous improvement is gaining momentum as project organisations are not only required to deliver projects within

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a given time and budget but are also expected to deliver high quality by increasingly demanding clients.

This paper presents a knowledge management framework for continuous improvement in project organisations. The paper starts with an outline of the research methodology and a brief discussion of the concept of knowledge management as well as its processes. The importance of a project knowledge base is discussed highlighting the motivation for a knowledge management strategy based on the experience of large project-based organisations in the construction sector in the UK. The different types of knowledge and various mechanisms for knowledge sharing (inter-project, intra-project and cross-sectoral learning) are also discussed. The paper concludes with an integrated knowledge management framework showing how project objectives can be aligned to knowledge management initiatives, and the impact of initiatives assessed for continuous improvement in a project environment.

RESEARCH METHODOLOGY

This study is part of an ongoing research investigating the relationship between KM and business performance. A variety of research methods including literature review, questionnaire survey and semi-structured interviews are used for the development of a KM framework for project based organisations. The literature review identified the types and dimensions of knowledge - people, process, and product knowledge - relevant in the context of construction project organisations. A questionnaire was sent out to senior managers and directors of large construction organisations to identify the key elements and factors that could hinder or facilitate the successful implementation of KM strategies. The literature review, the elements and issues identified through the questionnaire survey and semi-structured interviews form the basis for developing a KM framework. Through extensive collaboration with industrial partners, the conceptual framework will be developed, continuously refined and tested.

KNOWLEDGE MANAGEMENT

The growing body of literature on knowledge management reflects its strategic importance in the new knowledge-based economy. The transition to a knowledge economy is affecting, in varying degree, many sectors, industries and organisations. Knowledge management is underpinned by an organisational capabilities approach which emphasises innovation, learning and competence as the basis for improving business performance (Leavy, 1996).

There are various definitions for knowledge management (KM) generally illustrating the variations in scope and content. KM is defined narrowly, in some instances, to emphasise the capture, access, and reuse of information and knowledge using information technology (O'Leary, 2001). This definition implies that tacit knowledge can be converted to explicit knowledge using IT. However, it is generally accepted that tacit knowledge is more difficult to capture. But KM is now increasingly recognised to include the management of tacit knowledge as well. KPMG Management Consulting (1998) defines KM in a wider sense as 'a systematic and organised attempt to use knowledge within an organisation to transform its ability to store and use knowledge to improve performance'. The focus of KM in project organisations is, therefore, to use 'knowledge of best practice' from previous projects as a template to improve the performance of future projects.

Types of Knowledge

Knowledge is often classified into two distinct types: tacit knowledge and explicit knowledge. Tacit knowledge is stored in the heads of individuals and is difficult to communicate externally or to share. Explicit knowledge is captured or stored in project manuals, procedures, information systems, and is therefore, easily communicated or shared with other people or parts of an organisation. Construction project organisations use both codified and tacit knowledge for their processes to deliver various products. Explicit (codified) knowledge includes engineering principles, design code of practice, construction standards, whereas tacit knowledge includes the experience of estimating and tendering, practical design and work programming skills all acquired over time. There is a long tradition of apprenticeship scheme in the construction sector responsible for producing craftsmen often relying on their tacit knowledge to solve problems. Apprentices acquire their tacit knowledge through working with their masters and learning about craftsmanship by observation, imitation and practice, and not through formal instructions or textbooks. According to Marshall and Sapsed (2000) "organisations are depicted as storehouses of localised knowledge held by individuals and groups". The key issue is therefore to identify localised knowledge and transform it into productive knowledge that resides within the organisation to create value (Stewart, 1997).

Knowledge Management Processes

Knowledge management consists of five distinct but interrelated processes; discovery and capturing; organisation and storage; distribution and sharing; creation and leverage, retirement and archiving. The discovery and capturing stage is aimed at finding out where knowledge resides, whether in peoples' heads, processes or products. Examples include capturing tacit knowledge by bringing people together, discovering a database of products, experts or codified knowledge about processes. Knowledge organisation and storage deals with structuring, cataloguing and indexing knowledge so that retrieval can be done easily. Examples include the creation of database. Knowledge distribution and sharing is about getting the right knowledge, to the right person or part of the organisation at the right time. It requires awareness of the relevant knowledge or best practice. Examples include using technology to distribute explicit knowledge or by connecting those who have tacit knowledge with those who need it. Knowledge creation and leverage stage involves combining or applying knowledge in new ways to extend the overall knowledge of the business, and to exploit the new knowledge to improve business performance. Examples of knowledge creation include setting up project improvement and innovation processes to routinely monitor knowledge for new insight, whilst knowledge leverage include licensing or selling knowledge through for example software products. Knowledge archiving and retirement stage deals with treatment of knowledge that has already been used but not updated or knowledge that has not been used or is no longer valid. This include knowledge that is not of immediate use and relevance to the organisation but is placed in an archive to be retrieved as and when it becomes useful in the future. This stage is often ignored in the literature but it is becoming increasingly crucial in an era where information overload is a major problem.

THE PROJECT CONTEXT

From a project context, KM is a process of capturing, storing, sharing, and applying the different types of knowledge, whether tacit or explicit, by making them easily accessible and usable so that time is saved, performance is improved, and innovation is facilitated from project conception to completion. The project knowledge base is a function of the procedures put in place to transform knowledge. Knowledge can be found in people, processes and products. Knowledge about people is particularly crucial as knowledge primarily resides in people, not technology (Davenport, 2000). However, technology is an important enabler necessary to support the knowledge management process (see Figure 1).

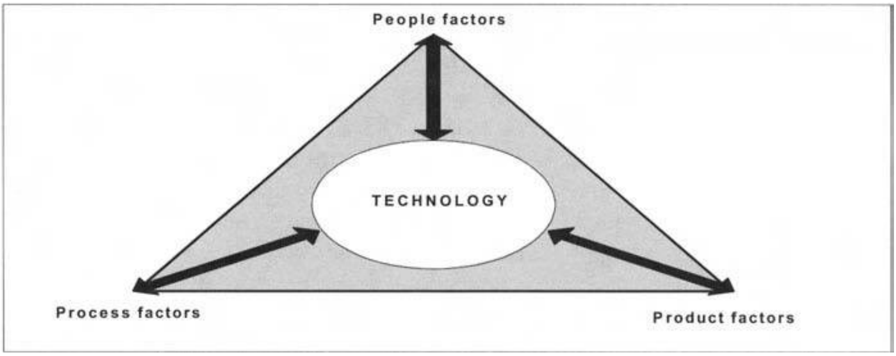

Figure 1 Context-based factors influencing a KM strategy. Source: Robinson *et al* (2001a)

Continuous improvement is achieved by applying knowledge of best practice from previous projects to improve the performance of future projects. Egan (1998) argued that improvement in the performance of the construction sector could be achieved by integrating the processes, people (teams) around the products. Decisions have to be made on what knowledge to manage about the project context i.e. key knowledge about products, processes and people. The context-based factors relate to the project environment and addresses issues of what is produced (products - goods/services), how it is produced (processes) and by whom (people).

Product-based factors relate to the characteristics of the services or goods, whether standardised or customised, mature or innovative (Hansen *et al* 1999). People-based factors relate to the type of individuals and teams, their knowledge, skill profile and problem solving styles (Hansen *et al* 1999). Process-based factors relate to technical considerations such as construction methods, and management considerations such as organisational structure and procurement systems (Carrillo *et al* 2000). The key to developing a successful KM strategy is to identify the key project knowledge and to understand the different types of mechanisms for sharing knowledge about processes, products and people. However, for a KM strategy to be successfully implemented the organisation has to be motivated.

Motivation for Knowledge Management

It is important to understand what motivates a project organisation to implement a KM strategy in the first place. Davenport, Long and Beers (1997) argued that motivation to create, share and use knowledge as an intangible asset is a critical success factor for virtually all knowledge management projects.

A recent survey shows that large construction project organisations are motivated to introduce a KM strategy for a variety of reasons (Robinson *et al*, 2001c). The most significant factors identified in the survey are the dissemination of best practice to key sets of employees and the retention of the tacit knowledge of key employees. Sharing of best practice knowledge to improve project performance is considered to be the most significant factor. Most project organisations recognise that considerable improvement in project performance can be achieved if 'best practice' knowledge within and outside the project environment are made readily available and utilised by project team members. They also recognise that a significant part of their key project knowledge are also in the heads of experienced personnel, which tends to move from project to project, and from one organisation to another. However, the overall effect of disseminating best practice and managing effectively the tacit knowledge of key employees is to continuously improve project performance. Other motivating factors identified include the need to respond to customers more quickly and to reduce rework. The task force on "Rethinking Construction" noted that up to 30% of construction is rework (Egan, 1998). An effective KM strategy can improve the dissemination of best practice knowledge, facilitate the management of tacit knowledge and the reduction of rework so widespread in construction projects. The overall effect will be a significant reduction in time, increased cost savings and improvement in quality.

Mechanisms for Learning and Knowledge Sharing

Project organisations have three distinct modes of learning and knowledge sharing: Inter-project, intra-project learning and cross-sectoral or support learning. However, the characteristics of construction projects such as discontinuities, fluid team membership, one-off nature of projects, and information flow between corporate boundaries, raise a number of challenges for managing project knowledge.

Inter-project learning takes place across projects by sharing lessons learned in previous projects to develop new knowledge for improving the performance of future projects. Documents relating to previous projects such as drawings, cost plans, bills of quantities, specification, work programme, project reports are often kept or archived for future references. In some cases, a summary of lessons learnt whether good or bad practices are also available following project closure. The scope for learning and sharing knowledge also depends on the type of project whether standard, traditional or innovative. The scope for sharing and re-using knowledge is greater in projects that rely on well-established standards at every stage of their design, manufacture and construction. It will also cost significantly less than non-standard projects as the benefit of reduced rework, re-use of drawings, reduction in uncertainty will improve project performance.

Intra-project learning takes place within a project by the creation and sharing of knowledge during the project life-cycle. Intra-project learning provides an immediate and direct opportunity to influence an on-going project as lessons learnt in earlier phases can be applied to subsequent phases for improvement. However, such benefits are not always fully realised as time is always a major constraint as a project progresses through different phases.

Cross-sectoral or support learning takes place outside the project sector environment. There are a lot of good management practices and processes in manufacturing, aerospace and other sectors not used in the construction sector. There is therefore considerable scope for improvement in construction project organisations by looking at best practices in other industries. Egan (1998) argued that there is a need for a radical improvement in the construction industry, and suggested that the industry could learn from other industries to improve processes and product development. Learning across the aerospace and the construction industries is the subject of an on-going research but knowledge transfer across business sectors is considerably less straightforward than commonly acknowledged (Fernie *et al,* 2001).

INTEGRATED KNOWLEDGE MANAGEMENT FRAMEWORK

An integrated approach to knowledge management reflecting the project context - processes, products and people - is necessary to transform organisational knowledge into productive knowledge (Robinson *et al,* 2001). The process, people or product shaping factors has implications for the type of knowledge to be managed, which in turn influences the KM strategy. Project managers faced with the need to deliver projects within a given time period by increasingly demanding clients are often under extreme pressure to make decisions. An effective KM strategy can be a powerful supporting tool for project managers. However, it is crucial to establish a robust project knowledge base and an effective framework for implementation.

Establishing the Project Knowledge Base

Knowledge in a project environment can be found in people, processes as well as products. Project organisations can be characterised by the types of projects they are capable of handling or the products they want to deliver. Construction organisations utilises a range of 'component products' to produce a range of 'end products' from small and simple buildings to large and sophisticated structures such as bridges and dams. The "component products" provided by manufacturers, suppliers and builders merchants are crucial in the construction of end products. Construction 'end products' are classified into three distinct types: standard construction; traditional construction; and innovative construction (Bennett, 1991). Innovative projects are needed where there is a requirement to satisfy the demand of some clients with unusual needs, or where established answers become obsolete as a result of market or technological changes (Bennett, 2000). Knowledge about clients, end-users and market characteristics are therefore important. The client type could range from 'one-off' or occasional clients with very little knowledge to repeat or major clients with expert knowledge about construction. End-users may have varying needs and aspirations. The market for the products could also be purely competitive, oligopolistic or monopolistic. The knowledge to be managed about the 'component products' and 'end products' of construction are therefore influenced by a combination of client, end-user and market variables.

The 'end products' required by clients might be different but the stages involved in production are essentially the same - from planning, designing to construction and maintenance. However, the technical and management processes used in construction vary in complexity. The technical processes could range from highly flexible approaches utilising various combination of tacit and explicit knowledge to fully automated processes relying on explicit knowledge codified in computer systems. The management processes also vary depending on the type of products to be delivered. Standard construction products are more effectively managed by programmed organisations relying on standardised detail designs and standard construction techniques (codified knowledge). Traditional construction products require professional organisations with the ability to interpret clients' requirements, and specialist contractors who are also able to interpret design information to manufacture and construct their own elements. Innovative construction products require problem solving or creative organisations to find new answers to fulfil the design requirements of clients arising from unusual needs that cannot be met by established answers using tacit knowledge (Bennett, 1991).

People-based factors relating to the characteristics of individuals and teams are also important. Bennett (1991) argued that while appropriate project management structures are necessary to tackle the different type of products, they are not sufficient to ensure an efficient construction industry. Competent teams (suppliers, designers and constructors) are vital for the construction process. Teams are the first levels of organisation above individuals and different kinds of teams are required to undertake construction. Standard and traditional construction require teams with basic knowledge and skills. However, creative teams are needed for innovative projects were the variables to be considered are often ill-defined and the required technologies need to be developed (Bennett, 2000). Creative or problem solving teams are designed "to bring knowledge to bear in solving *emergent problems*" (Dyer and Nobeoka, 2000). However, it is impossible to predict the skills and knowledge that will be needed for innovative construction. Team stability and composition also have a profound implication for knowledge creation, sharing and application. Egan (1998) noted that 'the repeated selection of new teams inhibits learning, innovation and the development of skilled and experienced teams. Bennett (2000) who argued that the best result comes from the same people working together on project after project supports this view. Under the traditional procurement system, teams are formed, often from different organisations, at the start of a project and disbanded when projects are completed.

This means that different project organisations are involved at different stages, with an unstable team often creating conflicting priorities and agenda due to different organisational affiliations. The benefit of KM is therefore perceived to be of limited value under such systems compared to long-term partnering arrangements, which promotes team continuity (Carrillo *et al* 2000).

The starting point for structuring project knowledge is to develop a knowledge map for capturing and sharing explicit knowledge, and also for serving as pointers to holders of tacit knowledge. Figure 2 shows a knowledge map with multiple level of details.

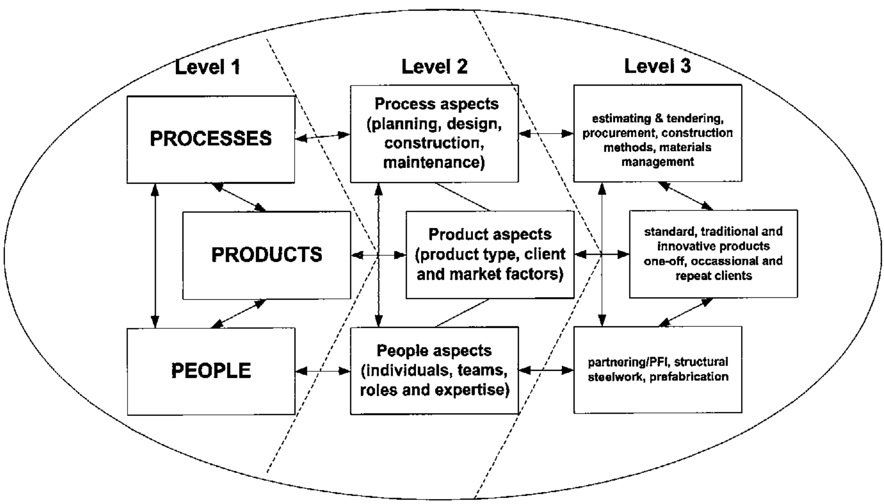

Figure 2 knowledge map with multiple level of details

The items or elements on the knowledge map can be text, drawings, graphics, numbers, stories, icons, symbols or models which can also serve as links to more detailed project knowledge such as those shown in Tables 1, 2 and 3.

Table 1 Examples of Process Knowledge Base

Sub-Processes	**Key Knowledge Issues**
• Procurement	Partnering, PFI, design and build, construction management, traditional contracting
• Estimating & tendering	Profit margins, overheads, bidding success rate, bidding costs, regional factors, sub-contract quotations
• Materials management	Structural steelwork, concrete
• Construction methods	Prefabrication, on-site construction,

Table 2 Examples of People Knowledge Base

Expertise	Key Experts/ Teams	Key Project Experience	Regional Experienc e	Location	Availability
Partnering, PFI	A23, B16, C20	Standard typeI Standard type II	R1 & R3	R2	09/02
Sub-contract quotations, overheads	A10, A22, C15	Traditional type I	R2, R3 & R7	R3	12/01
Structural steelwork	D25	Innovative type II	R5	R5	03/03
Prefabricati on	E45, F23	Innovative type I	R2 & R6	R6	11/01

Table 3 Examples of Product Knowledge Base

Product type	**Product name**	**Product Location**	**Product user characteristics (Client type)**	**Product cost (£ millions)**	**Other product characte ristics**
Standard type I	Housing	R1	Repeat		
Standard type II	Shops	R3	Occasional		
Traditional type I	Hospital	R7	Occasional		
Traditional	Bridge	R4	Repeat		

type II					
Innovative type I	Superma rket	R6	One-off		
Innovative type II	Stadium	R5	Occasional		

The knowledge map also serves as a continuously evolving project memory, forming a link between different knowledge sources, capturing and integrating new knowledge into the project knowledge base. It also enables project team members to learn from past and current projects through the navigation of information as well as the creation of new knowledge, by adding, refining and broadening the scope. The lists in Tables 1,2 and 3 are not exhaustive but illustrate a range of knowledge areas which construction project organisations may want to explore to continuously improve project performance. Knowledge maps are also used to bridge the gap between an organisation's base of knowledge resources and the work the organisation does. Formal measures could be set up to expand and refine the flow of knowledge.

Establishing a Framework for KM Implementation

There are several aspects to be considered in the implementation of a knowledge management strategy from a project viewpoint. It is important to identify the goals of the project, the types of knowledge the project needs and to develop appropriate KM initiatives, and then to evaluate the effectiveness of the KM initiatives for continuous project improvement. A three-stage framework for Improving Management Performance through Knowledge Transformation (IMPaKT) has been developed that examines project strategies, analyses the KM dimension of project objectives, and assesses the likely impact of KM initiatives on continuous project improvement. The IMPaKT framework encapsulates project knowledge from people, process and product perspectives (Figure 3).

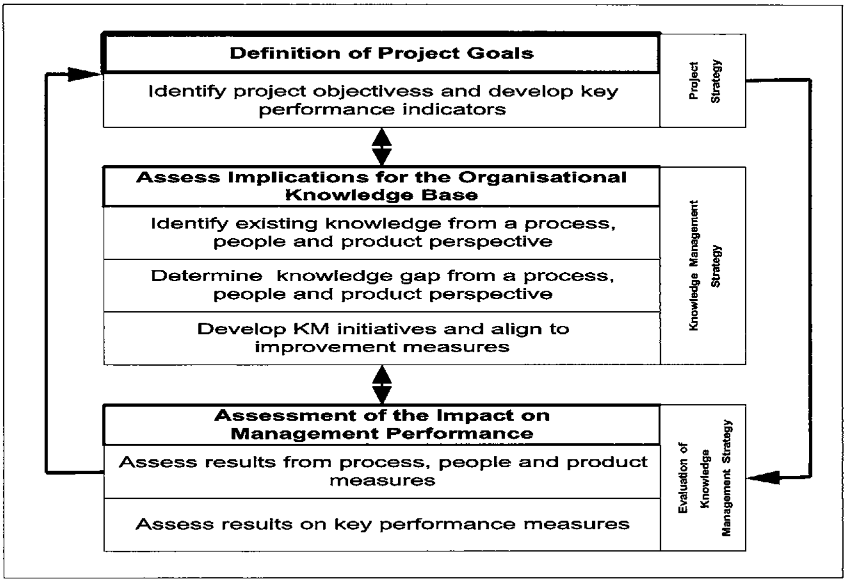

Figure 3 IMPaKT Framework. Source: Modified from Robinson *et al* (2001b)

Identification of Goals and Key Performance Indicators (KPIs)

The first stage involves identifying the critical success factors or project objectives in terms of quality, cost, time and other project variables to determine the responses required for improvement in project performance. The project objectives could be financial, safety, people, time or customer driven. This stage also involves determining appropriate measures or key performance indicators to reflect the project objectives. Examples of measures (key performance indicators) reflecting the objectives of the organisation at project level are shown in Table 4.

Table 4 Examples of Project KPIs

Criteria	Measures	Metric Definition	Current score	Target score
Time	• time for construction • time to rectify defects	• %age time overrun in construction • %age time overrun in rectifying defects		
Cost	• cost for construction	• %age cost overrun in construction		

	• cost of rectifying defects • cost predictability	• %age cost in rectifying defects • %age completed on budget		
Quality	• defects	• no. of major defects		
Client Satisfaction	• client satisfaction (product)	• nos. of complaints from client		
Health and safety	• reportable accidents • fatalities	• reportable accidents per 100, 000 hrs worked • fatalities per 100, 000 hours worked		

There is a growing concern in the construction industry that performance is a multi-dimensional measure. The need for comprehensive performance measurement approaches has recently led to the development and use of key performance indicators (KPIs) particularly in large construction organisations in the United Kingdom. Figure 4 is a flowchart of the key issues to be considered at stage one as well as the other stages of the implementation framework.

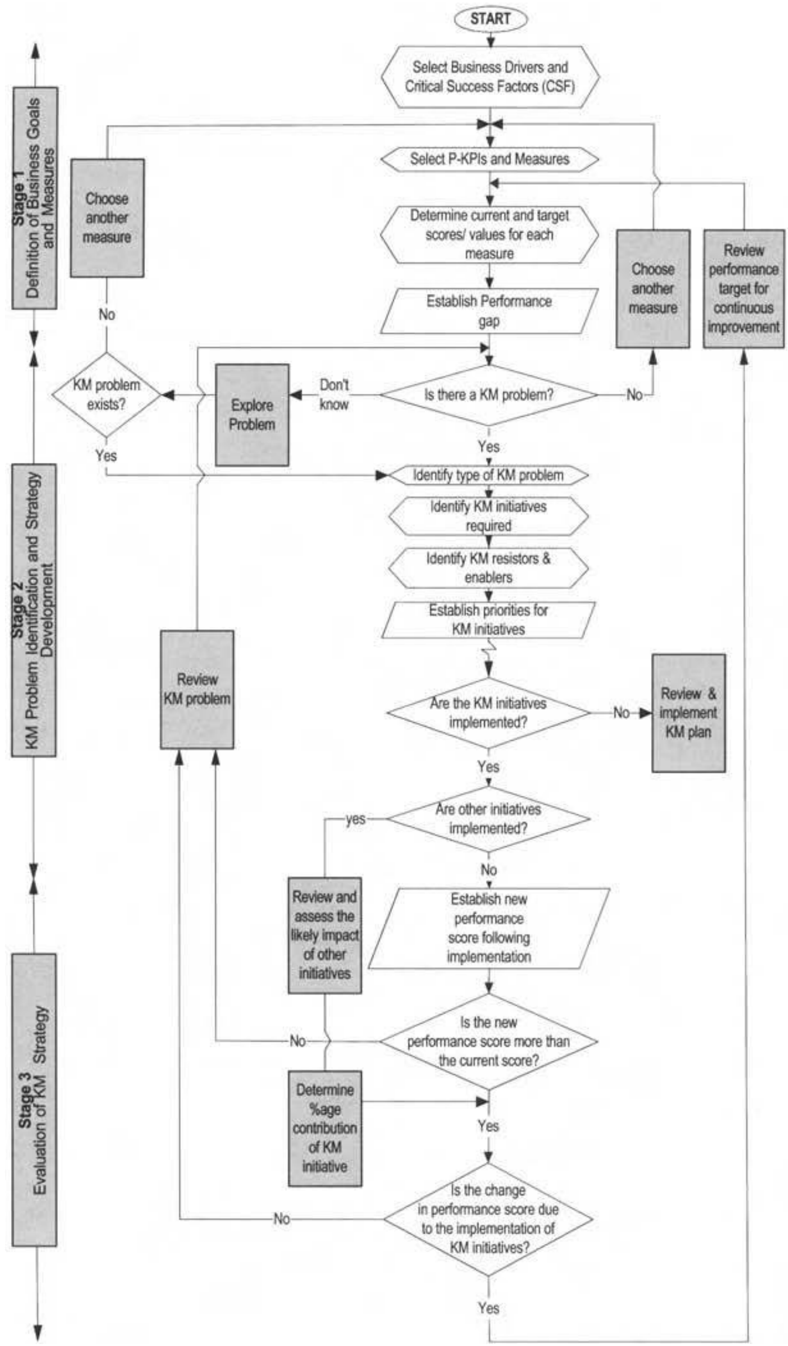

Figure 4 The IMPaKT flowchart

Identification and Analysis of the KM Dimension of KPIs

The second stage involves analysing the knowledge dimension of key performance indicators by relating them to their processes and people supporting those processes, identifying whether there is a knowledge management problem or not, and then selecting the appropriate KM tools for implementation. There may be a gap between the project objectives and the project knowledge required to continuously improve future performance. This will require an assessment of the project knowledge map in terms of current knowledge that exists ('as-is' situation) and future knowledge required ('to-be' situation) to determine the knowledge gap.

Specific KM initiatives can then be identified and implemented to improve project performance. For example, a KM problem associated with client satisfaction could be addressed by developing several initiatives. Knowledge about client types and their characteristics may have to be improved by utilising, sharing or applying more effectively information that already exist in the organisation about clients. A KM problem associated with cost overruns may include initiatives to improve time/ cashflow management of projects. It may also include other initiatives such as setting-up post-tender forum with clients or project closure meetings with project teams to share information with estimating and tendering team to improve bidding and cost management performance. A KM problem associated with heath and safety criteria may include initiatives to better understand the nature and causes of accidents on construction sites. This could mean developing more appropriate procedures to report on accidents, disseminate heath and safety procedures, create best practice manual on accident prevention and may even involve the appointment of a health and safety expert. A catalogue of KM initiatives could be identified for improving the key performance measures, which will constitute a KM strategy. These initiatives could then be prioritised, aligned to specific performance measures and then implemented, reviewed and monitored to achieve target performance scores or simply to close the performance gap.

Evaluating and monitoring continuous improvement

The third and final stage deals with the evaluation of the impact of KM initiatives on project KPIs. These KPIs may be people, process or product related. This stage is absolutely crucial, and is often the most challenging stage, as the justification of KM initiatives depends on how much benefit is expected. A range of KM tools can be selected for implementing KM initiatives. KM tools are systems, techniques and mechanisms used in the implementation of KM strategies. It includes both IT-based (hardware and software) and non-IT-based systems - criticalware (Robinson *et al*, 2001a). IT tools and technologies form one third of the time, effort, and money that is required to develop and use a KM system (Tiwana, 2000). The hardware tools

(KM infrastructure) comprise the platform required to support a project's knowledge management strategy.

The hardware system varies in size and complexity and includes the networks, computers, and cell and office phones, pagers, fax and voice processing machines. The software tools build on the KM infrastructure, and vary from simple databases to groupware to provide support for collaboration, and to intelligent decision support systems such as expert systems and business intelligence tools. The criticalware tools focus on the non-IT-based systems and range from simple informal dialogue (face-to-face conversation), mentoring to formal network meetings and research collaboration forum to harvest new ideas. As different KM tools are used for the implementation of KM initiatives, consideration should be given to their appropriateness in terms of functionality (i.e. ease of use, integration, focus and maturity) and cost. KM initiatives have to be evaluated in terms of the cost of implementation and expected benefits. For example, in terms of cost and time savings, personnel and operational savings and revenue enhancement.

The assessment process also requires an understanding of the interactions of the initiatives on the measures designed to monitor management performance. There are several distinct impact scenarios to be considered in the assessment process. Impact assessment methods are being addressed through detailed development of the IMPaKT framework as part of an ongoing research project (KnowBiz Project: www.lboro.ac.uk/KnowBiz) looking at the relationship between knowledge management and business performance.

CONCLUSION

Project organisations operate in a dynamic environment where it is increasingly difficult to compete without a continuous improvement strategy. Knowledge Management provides an opportunity for continuous improvement as it is underpinned by an organisational capability approach, which emphasises innovation, learning and competence as the basis for improving business performance. This paper has argued for a structured approach involving the development of knowledge map to capture best practice knowledge, whether tacit or explicit, to develop a project knowledge base to support future projects. A conceptual framework (IMPaKT) is also presented as the basis for an effective implementation of KM strategies as it considers the different types of project knowledge required based on project objectives, analyses the knowledge implications of key performance measures necessary for evaluating continuous project improvement. The framework also facilitates the assessment of the KM initiatives on project performance. The development of the IMPaKT framework is being addressed through an on-going research project investigating the relationship between knowledge management and business performance.

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A Whole Life Design Appraisal Tool

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INTRODUCTION

In the construction industry there are significant pressures forcing designers to change the way that they select components for new facilities. They include a shift from public sector to private sector financial responsibility, an increased demand for long-term value for money and emerging environmental penalties. There is, however, a lack of understanding of whole life design appraisal techniques in the sector, with the problem that issues such as running costs, component durability, sustainability and taxation all form complex scenarios.

This paper presents research into the development of an intelligent web-based tool for whole life design appraisal. The proposed platform will assist designers in the timely selection of the optimum mix of building components that gel together to suit both the immediate and long-term performance requirement of a facility. This is achieved by providing designers with "rule-of-thumb" guidelines that translate minimal attribute inputs into simple and concise outputs by interpreting uncertain data from a range of different sources. An inference mechanism will also produce a risk register to aid correct ownership of risk allocations, and thus help to provide lifetime insurability for cost and performance predictions.

CURRENT POSITION

Government authorities are moving from being owners and operators of assets into becoming intelligent clients purchasing long-term services. For over a decade the UK government has been putting some major construction facilities out to tender to the private sector. There is now a controversial commitment to developing further partnerships between the public and private sector. This is demanding a transformation of the roles and responsibilities of all those involved in the procurement and operation of new facilities.

The Private Finance Initiative is one such form of public private partnership and involves the public sector purchasing services instead of capital assets. The new facilities are built, financed and run by the private sector, with the government rationale that their involvement will save the public purse and bring private sector efficiency. Private sector contractors can therefore no longer simply build facilities and hand them over, but they need to take an involvement in planning the operation and maintenance of assets that are required to deliver value for money.

Achieving sustainability in construction procurement is also becoming a vital issue, particularly with green tax bills due to come into effect (Pearson, 2001). The government has put together a framework and set of goals to move and to measure progress in a sustainable direction by 2003 (Office of Government Commerce (OGC), 2000). Included are commitments that will result in procurement in line with value for money principles on the basis of whole life costs, less waste during construction and operation, targets for energy and water consumption, the protection of habitat and species, targets developed in terms of "respect for people" and a contribution to the goals of less pollution, better environmental management and improved health and safety.

To produce satisfactory commercial results in response to these challenges, new private consortiums must therefore design facilities with the new fourth dimension of whole life performance in mind. This change of approach, however, is not without difficulties, particularly on the financial negotiations and associated risk allocation, with whole life cost calculations being at the heart of the problem. Whole life costs include the reconciliation of all expenditure and revenues associated with the acquisition, operation, maintenance, renewal, adaptation and disposal of a facility.

Recent research interviews with leading design practices found that it is believed that whole life cost data is not as good as it could be, but it is sufficiently adequate to make an informed decision. The main problems are that the required data is not easily accessible and component performance risk statistics are rarely being fed back from facilities managers to designers. The cause of the latter fault is twofold. Firstly, most occupiers are not storing data efficiently, meaning that it is very difficult to retrieve information. Secondly, designers do not have the free time to take a committed interest in a finished product, and they are even reluctant to do so because it may expose them to liability beyond their present obligation.

Designers therefore often have to rely on intuitive estimates prepared by quantity surveyors. These are the construction cost consultants, to whom designers would prefer not to depend upon. In this predicament designers feel that it is too easy for data to be manipulated to suit an individual's attitude or bias. This is resulting in strange anomalies and inconsistencies, using so many assumptions that the results are almost futile.

Additional random discussions with other researchers in the whole life domain, together with contractors, manufacturers and clients, have subsequently confirmed the problem that the industry is having with determining reliable whole life cost predictions. Despite a great demand for whole life design appraisals to be carried-out, it is rarely being done properly. Data accessibility and risks management are the biggest problems facing design consortiums, and there is an urgent need for a new integrated appraisal tool for use during the early design stages of a proposed facility.

DATA FOR WHOLE LIFE APPRAISAL

Nearly twenty years ago Flanagan and Norman (1983) explained that it is unfortunate that the published sources of historical whole life cost data do not have sufficiently wide coverage to allow their effective use. Today, one of the most comprehensive occupancy cost information in the UK is published by Building Maintenance Information (BMI). BMI compiles several appropriate documents, including an annual maintenance price book (BMI, 2001a), quarterly cost briefings (e.g. BMI, 2001b) and special reports (e.g. BMI, 2001c). These are all useful sources of cost data for enabling designers to build-up composite component and elemental rates for the purposes of whole life design appraisal. The effective use of such information is demonstrated in BMI's occupancy cost plan studies (e.g. BMI, 2000). However, the reality is that designers do not have the time or resources to put the technique into practice when attempting to optimise project solutions during design briefings.

In most early stage whole life design appraisal situation, BMI data will only allow indicative square metre rates to be applied to total gross floor areas to give strategic budgetary estimates. This rate gives no consideration to the often-unique mix of components for a scheme, and the data sample sizes, specification supporting text and risk analyses are often inadequate. Quantity surveyors believe that initial capital cost estimates based on the cost per square metre method is insufficient and therefore a risky approach to adopt (Jackson, 2000). They prefer to base forecasts on approximate quantity measurements for individual components. The same rationale applies to whole life cost calculations.

Should adequate time be made available to compile an occupancy cost estimate based on approximate quantities, then the results will be most beneficial for aligning maintenance and adaptation requirements with the whole life business performance plan for a proposed facility. This will be achieved by selecting components that maximise functional continuity and minimise temporary disruptions or relocations. However, the problem with the BMI approach is that essential information, such as the service life of components, taxation and the cost of cleaning, is still required from other sources. This issue is the downfall of the BMI method for use by designers because they are required to search for information from many additional organisations, including manufacturers, regulatory authorities and contractors. This task would be an onerous one even for the quantity surveyor, whose efforts would need to be in addition to the limited time constraints that are normally available to prepare the capital cost estimate (Jackson, 2000).

The OGC (2001a) has stated that historical whole life cost data is not appropriate. Their procurement guidance concludes that where historical data is available, it reflects past mistakes, and that it is always preferable to estimate the costs from first principles. However, this could be construed as contradicting a sister guidance document that promotes project evaluation and feedback (OGC, 2001b). What is therefore required is a system that will use intelligent mechanisms and search engines to quickly bring the different sources and types of whole life data together. Vast "banks" of numbers exist, but they are not being utilised. There is a need to connect these islands of information in an easily accessible way to enable designers to efficiently evaluate the pertinent issues for the purpose of whole life design appraisal.

DEVELOPMENT OF A CONCEPTUAL MODEL

In developing a conceptual model for whole life design appraisal, it is useful to consider the way in which designs develop for new build facilities. Approaches to design can depend on the client, the procurement route and the type of facility, and there are many different ways of getting from "A to B". Generally, approval gateways exist for concept, scheme and detailed designs, however, the key issue is to establish what type of components should be specified before it's design modelling begins. As nearly all clients are financially driven, this primarily involves calculating how much a facility is going to cost, and thus providing a viable framework for subsequent design development.

It is generally believed that approximately eighty per cent of the whole life costs are built into a facility during the first twenty per cent of the design period. The initial design brief of outline objectives should reflect the period from design and construction, to the immediate user requirements and the long-term occupancy plan for the proposed facility. The facility's design life and frequency of refits must therefore be anticipated, and the results of the appraisal should be used to influence what is to be designed. This can be achieved by making future running costs highly visible, thus convincingly proving that it is beneficial to spend more funds on the initial product to make savings later.

Currently available commercial whole life design appraisal software packages lack the flexibility and information needs required by designers. They are deficient because they are not link to the best sources of cost and performance data, and do not provide the "rule-of-thumb" guidelines needed by designers when there is pressure to quickly specify components in the critical early stages of a project. In recognising this shortfall as a research opportunity and challenge, the principal aim of this paper is to demonstrate the potential of an intelligent whole life design appraisal tool, to be used by designers, for selection of the optimum mix of building components for a proposed new facility.

A WEB-BASED PLATFORM WITH SOCKETS

To provide designers with the relevant decision-making information, accessible timely and concisely, an intelligent portal is proposed. This will automate the laborious and time-consuming task of data mining. The Internet is the means of achieving this, and it's unique potential has been proven with similar tools that are available to the general public, for example, to select a rail or airline ticket, and in the construction sector, such as through the Building Cost Information Service (BCIS, 2001), where the service has seen a 70% growth in subscribers (Chartered Surveyor Monthly, 2001). The proposed whole life design appraisal tool will act as a web-based platform that will have several "sockets". Suppliers of the various whole life design data sources will provide the "plugs" for the sockets.

So far the emphasis in this paper has been on the cost element of whole life design appraisal. However, when choosing between the various competing options that fulfil the minimum performance requirements, several other important factors enter the equation. A whole life design appraisal summary for a building component should comprise eight constituents:

- Installation time – The programme period required to design, manufacture and position the component in situ.

- Capital cost – The price that must be paid for design, purchase and installation of the component.

- Forecast service life – The period of time after installation that the component will meet the minimum performance requirements.

- Operation and maintenance cost – The running cost of the component during its whole life use, including any necessary renewal and adaptation cost.

- Disposal cost-value reconciliation – The balance between the cost of removing the component from the facility and any salvage value.

- Monetary benefits – Income such as an increase rental value for providing a facility with a particular type of component.

- Qualitative benefits – The component's performance value for the "softer" issues that cannot be easily quantified, e.g. aesthetics and user-satisfaction.

- Life cycle assessment – Evaluation of the green / sustainability issues of the component.

This list reflects the key output information for the proposed tool. It must be backed-up with detailed build-ups explaining the occupancy instruction applied, the sources of information used and the assumptions made.

The initial conceptual model focuses on the first five items listed above, i.e. the time and cost features. This is because it is within the bounds of current possibilities to collect objective data for these items. Monetary benefits, qualitative benefits and life cycle assessment scores are softer issues that are more subjective and thus difficult to quantify. They are, however, still regarded as being important ingredients, and they should be incorporated in future models.

Having identified the outputs from the tool, it is possible to work backwards and determine the required inputs. The inputs from designers for whole life design appraisal of a building component are limited to just eight parameters:

- Facility type / functional location – This determines the typical performance properties of the component and the agents of degradation.

- Site location – The geographical positioning influences the installation time and cost of the component, with the regional weathering agents affecting the forecast service life.

- Base date – The future running costs of the component will be discounted to present day and considered alongside the capital cost.

- Approximate quantity – This will be used for all cost and installation time calculations.

- Design life – The period that the component is required to be an integral part of the proposed facility before being made obsolete.

- Minimum service life – The period that the component must be functional before needing to be replaced.

- Speed of installation – To be viable the component must comply with the programme that is set to deliver the facility on time. This parameter is also applicable to replacement time periods.

- Key component interface – This will allow the adjoining agents of degradation to be identified, and also used to detect any conflicts between the final mix of component specified.

In order to achieve the "rule-of-thumb" guidelines needed by designers, it is necessary to translate the attribute input information into simple and concise output data by interpreting the uncertain figures from the range of different sources.

HOW THE TOOL WILL WORK

Prior to appraising a component, the facility type and site location should be known. The first task is then to consider the facility's whole life and strategic performance requirements (ISO, 2000). This study must determine the overall design period and lead-time, tender and site construction periods, facility's design life, and anticipated intervals for refits, refurbishments and change of use. The plan can then be presented in a simple Gantt chart, as shown in the example in Figure 1. This plan may then be used to determine the minimum service lives of individual components across the whole life of the facility. It will help to identify the components that are to be permanent and those that must be replaceable. It is also necessary to prepare a list of component approximate quantities and a functional area schedule, which must be measured from preliminary drawings of plans and elevations. Upon selecting a component to be appraised, the designer will refer to the Gantt chart to determine the specific timing related to the component. This will then be plotted on a more detailed component level programme.

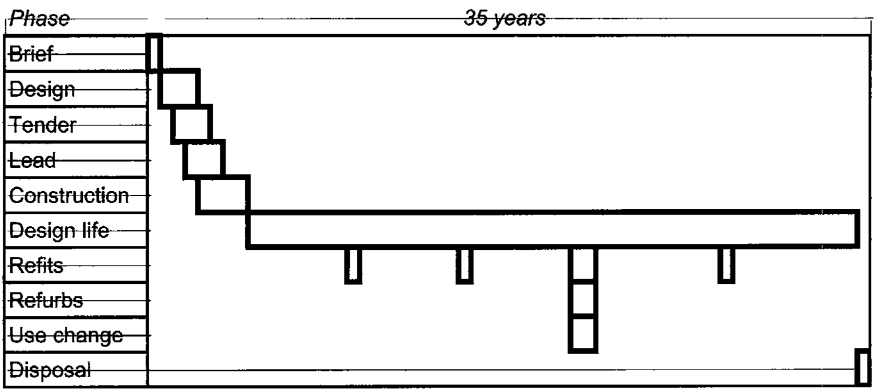

Figure 1 The whole life of a facility

Figure 2 shows how the tool will work. First the component's functional performance requirements and agents of degradation will be extracted from the facility's database. These will be presented to the designer in simple "rule of thumb" format for designers to accept or modify. Next, the components that meet the minimum performance criteria will be extracted from the component database. The forecast service lives of the options will be adjusted based on the facility's agents of degradation and site location (i.e. weathering agents). Those that have a life less than the required minimum service life will be omitted, and for the remaining ones the installation, operation, maintenance, and disposal constants will be extracted, and the information used to calculate total times and costs utilising appropriate databases.

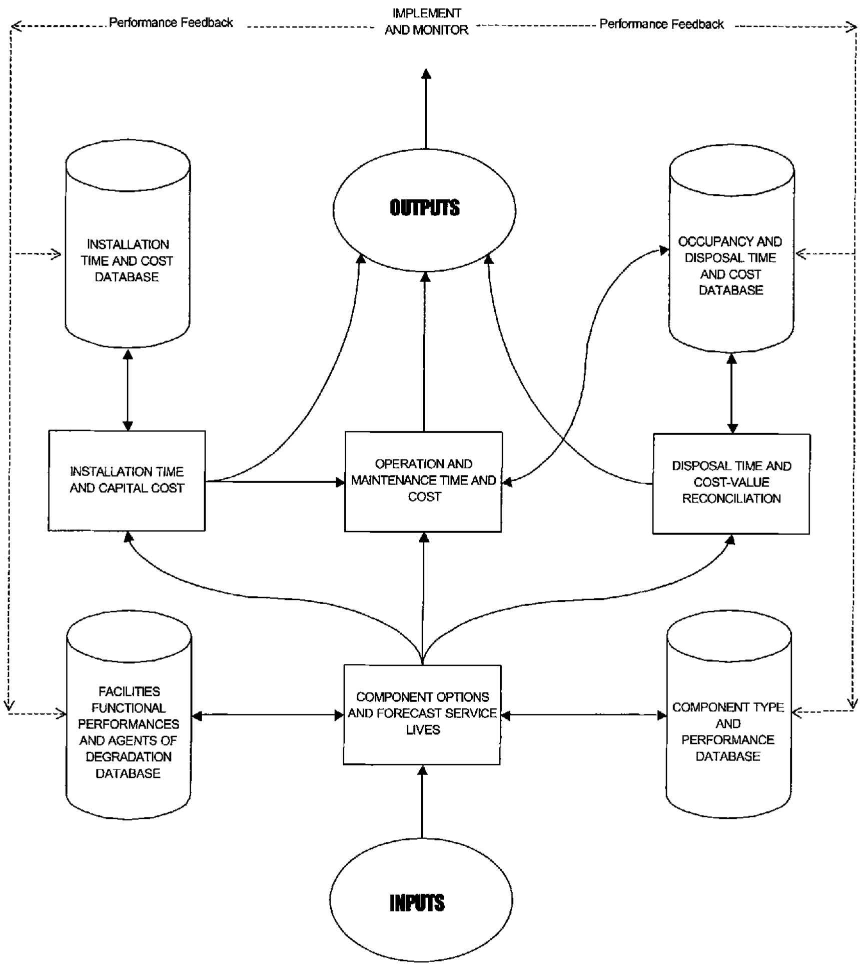

Figure 2 A model for whole life design appraisal

The results will be presented in a simple format for decision-making, and the designer will then send the selected component specification to a total project model. This process will be repeated for each component and, upon completion of every component, a clash-detection system will be run, detecting any mismatch between the selected components. Where they are found to be incompatible, the system will do further searches and suggest alternatives. It will also detect any knock-on effects, for example, the selection of a particular flooring system may affect the structural height between floor levels, the loading and the foundations design. Results will also include the ancillary cost data required (e.g. skirting, underlay and trims for a floor finish), and it will produce cash-flow graph for the whole life of the facility. The tool will automate production of the outline design brief.

The Davis Belfield & Everest (1977) method of initial capital cost estimating will be adapted for whole life cost estimating, using size and specification to determine budget costs. A predictive model will make explicit the assumptions about uncertainty, and also utilise historical feedback data as a means of validating the allowances for the risk of repairs and failure. The data that has an effect on the results will automatically be identified, and Flanagan et al's (1987) method of sensitivity analysis and Monte Carlo simulation is to be adopted.

Behind the simple facade will be complex dynamic simulations running with optimisation algorithms. The Monte Carlo simulation method of evaluating an influence diagram has become known as "dynamic risk analysis" (Simon et al, 1997). With this approach the influence effects generated at one node are transferred to the next, where they are combined with all other influences before being transferred to the next node, and so on until the final node is reached. Designers will then be able to carry out "what-if" analyses of the different options, using various combination of the variables, with the perceived most likely scenario being compiled in a project risk register. This will aid the correct ownership of risk allocations, and thus help to provide insurability for cost and performance predictions.

The four databases shown in Figure 2 will probably be managed by different specialist organisations. The facilities functional performances and agents of degradation databases may be maintained by client organisations. The component type and performance database could be maintained by established specialists such as Building Performance Group (BPG, 2001) and Housing Association Property Mutual Limited (HAPM, 2001), being achieved through collaborations with component manufacturers. The installation time and cost database might be maintained by publishers such as the BCIS and Spon (Davis Langdon and Everest, 2000). Finally the occupancy and disposal time and cost database may be run by experts such as BMI, who could extend their present service through collaboration with statutory authorities, operation and maintenance contractors and insurance companies. To be effective each database should rely on both original first principle data and performance information fed back from the facilities supply chains. The latter will be achieved through proposed feedback mechanisms that will allow probability profiles to be constructed for the purposes of future risk management simulations. This will reduce the need for designers to take a whole life involvement in facilities, as the tool's feedback system will automate the process of learning from past performance.

ADVANCED SOLUTIONS

Future holistic whole life appraisal models will be able to produce more detailed specifications as designs develop, including complete operation, maintenance and health and safety manuals. When appropriate the designers will be able to import intelligent objects that are supplied via manufacturers on the web into their CAD packages. These will contain all the whole life data in a dynamic form. The selected virtual objects will live with the actual built facility, linking to sensors and building management systems that are embedded in the structure, fabric and services. These will automatically monitor the costs and performance of components, enabling recorded data to be fed back to designers. In achieving these aims, greater collaboration will be required between all individuals involved throughout the supply chain of a facility, in particular from clients, manufacturers, designers and facilities managers.

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Risk Analysis for Decision Support System of Risk Management in Building Projects

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ABSTRACT

This paper presents the risk analysis for decision support system of risk management from the viewpoints of site managers in Japan. In the past decade, both inside and outside of Japan, a lot of studies and researches have been done on the problems concerning the risk management process, the contract relation, and the development of risk analysis technique. However, there are very few studies discussing the project risk from the viewpoints of jobsite engineers (Tsai et al., 2001). Especially risk management, which has been usually processed in the empiricism, is not considered very much on the construction sites in Japan. Moreover, the studies about risk management are still in a qualitative discussion concerning the reasonable relationship and responsibility allocation among the related stakeholders in the contract. However, it is necessary to understand the quantitative mechanism of project risk as much as possible to proceed risk management in the construction site properly, and set up the risk strategies by trade-off of risk and cost to reduce the project risk (Tsai et al., 2001).

This study started with a discussion about the concept and the description of project risk with 40 site managers by brainstorming. And, 650 risk occurrence causes in very concrete description are emerged. The 105 risk categories (see Table 1) and 251 risk occurrence causes are classified in abstraction description based on these 650 risk occurrence causes. In the questionnaire survey, the quantitative and qualitative data of about 251 risk occurrence causes were collected from 22 construction projects in Kansai area of Japan. These data are analyzed from multiple dimensions to search the co-relationship among risk causes, risk strategies, project phases, and risk results. Finally, the framework of analysis model and the decision support system of risk management in the construction phase of construction projects are developed.

PURPOSES

The following are the two main purposes of this paper:

1) To clarify the risk strategies, the risk results, and the generation time of the project risk, and to realize the realities of risk management in Japan.

2) To propose framework of the decision support system which can search better solution and generate the risk strategies for the project manager.

THE CONSIDERATION OF QUANTITATIVE ANALYSIS

In order to achieve the research purpose 2), the evaluation method of two-dimension which is normally used for the ranking of the risk is introduced to evaluate the risk (Zhi, 1995; Marshall, 2001). In two-dimension, each of the impact and probability is made in a scale between 0 and 1. The impact is taken in one axis, and the probability is taken in another axis, then the risk is evaluated at the same time for these two axes. In other words, as shown in the Equation (1), “Risk is probability multiplied by impact”. The probability in this research indicates a simple relative frequency, where the risk occurrence cause happened according to the experience of the respondents. And, the impact indicates the size of influence given to the project when the risk occurrence cause happened.

However, the risk occurrence cause with “high probability and low impact” or “low probability and high impact” in a project will be neglected easily by this evaluation method. In other words, it is undesirable to evaluate the risk only by the size of R_i as the attributes of the risk are not considered (Willams, 1994). So, in this research, the values of probability and impact evaluated by two-dimension are the average of the answers of 22 respondents, but not for an individual project. Moreover, the analysis result is verified from the viewpoints of controllability, stage, risk strategy, and risk result concerning the risk occurrence cause.

Table 1 Risk Categories.

Risk cause	Risk cause	Risk cause
A. Natural phenomenon	37 D9.Trade restrictions	72 Gb5.Excessive competence
1 A1.Earthquake	38 D10.Language barrier	**Gc. Industry**
2 A2.Landslip	39 D11.Nationalise/private	73 Gc1.Monopoly conference
3 A3.Settlement	40 D12.Official	74 Gc2.Union

	judgement	
4 A4.Fire	41 D13.Lobby (legal/illegal)	75 Gc3.Patent
5 A5.Heavy rain	**E. Safety/ Environment**	76 Gc4.Overcompetition
6 A6.Typhoon	42 E1.Pollution	**H. Partners**
7 A7.Strong wind	43 E2.Waste control	**Ha. Skilled Labour**
8 A8.Rain	44 E3.Burial heritage	77 Ha1.Lack of manpower
B. Economic/Finance	45 E4.Accidents	78 Ha2.Low quality
9 B1.Inflation of wages	46 E5.Diffficulty of access	79 Ha3.Low morale
10 B2.Inflation of material	47 E6.Limitation of work time	80 Ha4. Drawing understanding
11 B3.Currency change	48 E7.Subway/Railway	81 Ha5.Communication
12 B4.High tax	49 E8.Third party's objection	82 Ha6.Sense of safety
13 B5.Inflation	50 E9.Neighbours' complaints	**Hb. Subcontractor**
14 B6.Deflation	51 E10.Undergrond conditions	83 Hb1.Bankrupt
15 B7.Interest change	**F. Construction**	84 Hb2.Local Particularity
16 B8.Difficulty of financing	52 F1.Special method	85 Hb3.Insufficient technical
17 B9.Decrease in demand	53 F2.New technology	86 Hb4.Coordinate with others
18 B10.Strong Competitor	54 F3.High quality standard	87 Hb5.Mutiple projects
19 B11.Fall of land price	55 F4.New materials	88 Hb6.Lack of mobilization
C. Contract	56 F5.Experimental difficulty	**Hc. Consultant (Designer)**
20 C1.Unequal regulations	57 F6.Insufficient site survey	89 Hc1.Constructability

21 C2.Vague articles	58 F7.Insufficient planning	90 Hc2.Vague drawing/ spec.
22 C3.Opacity at terms	59 F8.Insufficient procurement	91 Hc3.Scope of work
23 C4.Dispute of participants	60 F9.Insufficient coordination	92 Hc4.Supervision ability
24 C5.Unfair arbitration	**G. Team/Human**	93 Hc5.Design change
25 C6.Change of contract	**Ga. Jobsite**	94 Hc6.Fair standpoint
26 C7.Insufficient insurance	61 Ga1.Plan ability	95 Hc7.Ability of iobsite staff
27 C8.Excessive guarantee	62 Ga2.Management ability	96 Hc8.Decision making
28 C9.Missing of estimation	63 Ga3.Coordination ability	**Hd. Client**
D. Political/Society	64 Ga4.Insufficient staff	97 Hd1.Feasibility study
29 D1.Change of laws	65 Ga5.Human allocation	98 Hd2.Unreasonable require
30 D2.War/revolution/riot	66 Ga6.Personnel changes	99 Hd3.Nominated subcontract
31 D3.Unstable policy	67 Ga7.Sense of responsibility	100 Hd4.Late payment
32 D4.Complicate procedure	**Gb. Headquarters**	101 Hd5.Coordite with official
33 D5.Human relations	68 Gb1.Severe norm	102 Hd6.Trust in consultant
34 D6.Disagree restrictions	69 Gb2.Deficit contract	103 Hd7.Ability of jobsite staff
35 D7.Bribery/rot	70 Gb3.Short schedule	104 Hd8.Financing/Bankrupt
36 D8.Equipment restrictions	71 Gb4.ISO	105 Hd9.Maintence guarantee

$$R_i = (P_i / 100) \times (I_i / 10) \tag{1}$$

Where

R_i: The risk of risk occurrence cause i

P_i: The average probability of risk occurrence cause i, $0 \leq P_i \leq 100$, unit: %

I_i: The average impact of risk occurrence cause i, $0 \leq I_i \leq 10$

ANALYSIS

In this research, the collected data is analyzed from five viewpoints as written below.

Evaluation of Two-Dimension by Pareto Diagram

In order to exclude the risk occurrence causes which have obviously small influence to the project, the R_i of risk occurrence cause calculated by Equation (1) was enumerated in the descending order by the Pareto analysis (see Figure 1). The contributing ratio (c_i) was evaluated in the ratio of R_i of an individual risk occurrence cause to accumulation R_i of the entire risk occurrence causes by Equation (2). The accumulation contributing ratio (C_i) was evaluated in the ratio of accumulation R_i in the descending order of risk occurrence cause i to accumulation R_i of the entire occurrence causes by Equation (3). In addition, accumulation contributing ratio 0.8 was assumed to be a threshold. As a result, about 60% of the entire risk occurrence causes, 152 in total are extracted. The risk occurrence causes of lager R_i are "C102 Inappropriate contract term to the content of construction, cost overrun seems to happen" of "C Contract", "E101 The noise, the vibration, and the dust are troubled to neighbours" of "E Safety/Environment", "Ga109 Improper schedule for each work" of "Ga Jobsite" , "Gb302 Contract schedule is not enough" and "Gb204 The decrease in the quality is not permitted as for the deficit contract" of "Gb Headquarters", etc.

The risk occurrence causes which hardly exist in normal projects or occur only in special projects are excluded by this evaluation method.

$$c_i = \frac{R_i}{\sum_{i=1}^{251} R_i} \tag{2}$$

$$C_i = \frac{\sum_{k=1}^{i} R_k}{\sum_{i=1}^{251} R_i} \qquad (3)$$

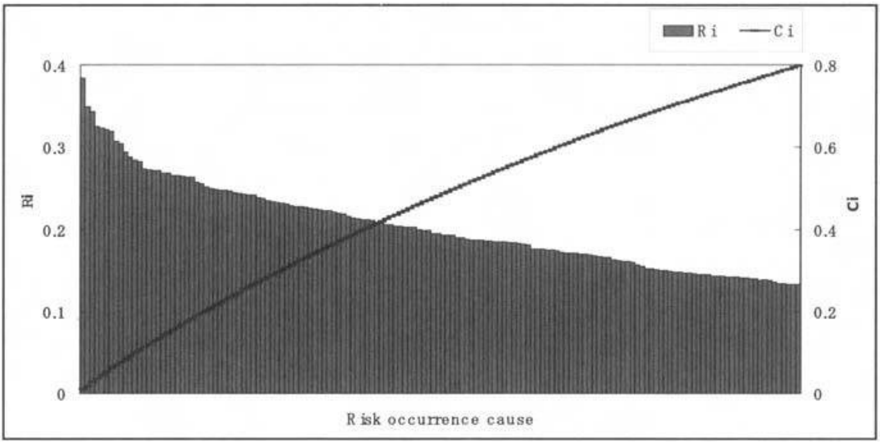

Figure 1 R_i and C_i of Risk Occurrence Cause

Distance of Controllability

Because the controllability of risk occurrence cause is a subjective judgement by a personal experience of the project manager, it is necessary to exclude the risk occurrence causes with big difference in the evaluations of respondents and without a constant consensus. The concept of distance D_i of the controllability concerning risk occurrence cause was introduced, and the distance D_i was evaluated by Equation (4). The risk occurrence causes with distances over 0.35 were excluded and deemed that the disagreement of the judgement was large. For instance, the distance of "Hc702 The procedure of finish work is not observed" of "Hc Consultant (Designer)" is 0.1. On the other hand, the distance of "E601 Working hours and the vehicle operation time are restricted" of "E Safety/Environment" becomes 0.88. And, the distance of "B4 High tax" of "B Economy/Finance" is 0.35 (see Figure 2).

The risk occurrence causes have a constant consensus like "F101 Unfamiliar construction or construction method" and "F102 Inappropriate construction method is adopted" of "F Construction", etc., which contractor should face everyday.

$$D_i = \sqrt{(P_{i1}/100 - P_{i2}/100)^2 + (I_{i1}/10 - I_{i2}/10)^2} < 0.35 \quad (4)$$

Where

P_{i1}: The average probability of risk occurrence cause i in "controllable"

P_{i2}: The average probability of risk occurrence cause i in "uncontrollable"

I_{i1}: The average impact of risk occurrence cause i in "controllable"

I_{i2}: The average impact of risk occurrence cause i in "uncontrollable"

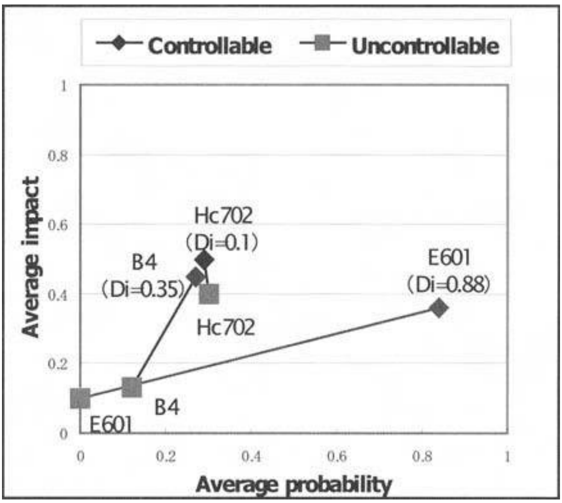

Figure 2 D_i for Controllability

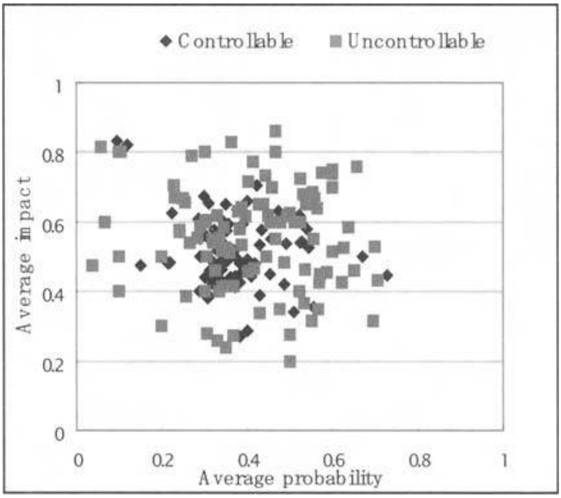

Figure 3 D_i less than 0.35 and C_i less than 0.8

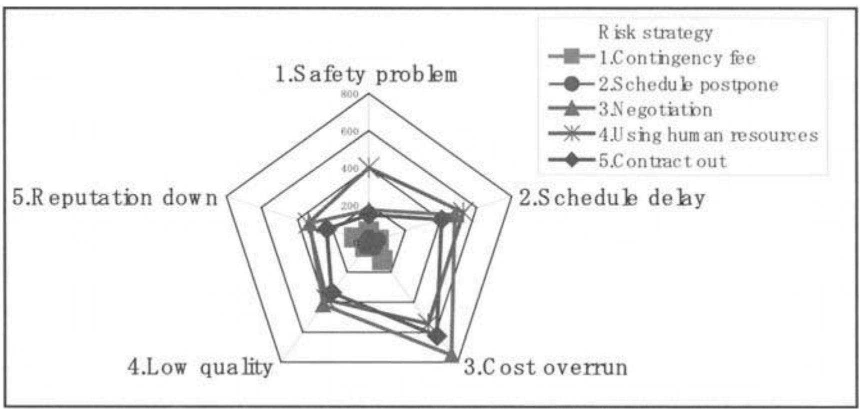

Figure 4 The Risk Strategies for the Risk Results

Distance less than 0.35 and Accumulation Contributing Ratio less than 0.8

The answers with high reliability for the risk occurrence causes with large influence to the project were extracted by using the evaluation of 4.1 and 4.2 at the same time. By comparing the distribution of 104 risk occurrence causes, which were extracted as mentioned above, with the distribution of 251 risk occurrence causes, it was found that the average probability concentrates on [0.1, 0.8], and the average impact concentrates on [0.2, 0. 8] (see Figure 3).

In the following, the 104 risk occurrence causes were used to analyze.

Risk Strategy and Risk Result

In order to clarify the current state of risk management, the risk occurrence causes were analyzed from the viewpoints of risk strategy and risk result. Generally, the risk strategies of "Negotiation" and "Contract out" are used for the risk occurrence causes which are uncontrollable, the risk strategies of "Using human resources" and "Negotiation" are used for the risk occurrence causes which are controllable. In addition, to examine the relationship of risk strategy and risk result in detail, Figure 4 was obtained by the following method. That is, certain risk strategies should be considered by project managers to prevent the generation of risk result because the occurrence of certain risk occurrence causes. The relation between risk strategies and risk results was derived by this consideration.

The risk strategy of "Schedule postpone" is hardly used because of the restriction of keeping contract schedule on time strictly on the jobsite in Japan. And, the risk strategy of "Using human resources" is used widely for all the risk results. Because all of the project risks can be reflected on the cost in a certain degree (Raftery, 1994; Isaac, 1995), most of risk occurrence causes are related to the risk result of "Cost overrun" (see Figure 4).

Ranking Analysis

The risk occurrence cause appearing strongly at a stage of the project was evaluated by Equation (5) for the value of R_{ij}. The five stages are defined as follows: "Before commence of construction", "Structure work", "Finish work", "After final inspection", and "Entire construction phase" of the project. The ranking of risk occurrence causes shows the relationship, strong with the stage of "Before commence of construction", is also strong with each stage afterwards. But the relationship, strong with the stage of "After final inspection", is not strong with other stages. For instance, the relationship of "C102 Inappropriate contract term to the content of construction, cost overrun seems to happen" is strong with every stage, but the relationship of "C801 It is difficult to hold the maintenance fee" is only strong with the stage of "After final inspection". Strength of the relationship with the risk results was evaluated by the same method. The relationship, strong with the risk results of "Schedule delay" and "Cost overrun", is also strong with each risk result. But the relationship, strong with the risk result of "Safety problem", is not strong with other risk results. For instance, the relationship of "C101 Inappropriate contract term to the content of construction, delay seems to happen" is strong with every risk result, but the relationship of "F702 The safety check is insufficient to the height works" is only strong with the risk result of "Safety problem". Generally, the risk occurrence causes having strong relationship with every stage and every risk result are C101 and C102 of "C1 Unequal stipulation", "Gb303 Recognition to the schedule of client is weak" of "Gb3 Headquarter", "Hc202 There is no clear answer from the designer due to the lack of the detail drawings" of "Hc2 Consultant (designer)", etc.

The project managers on the jobsite are expecting the designer to have a fair viewpoint and a contract without biases. Moreover, it is a reality that the risk strategy of "Schedule postpone" cannot be used, and the risk strategies of "Negotiation" and "Using human resources" are used frequently even if the severe schedule is recognized.

$$R_{ij} = \frac{P_i}{100} \times \frac{I_i}{10} \times \frac{N_{ij}}{N_i} \qquad (5)$$

where

P_i: The average probability of risk occurrence cause i

I_i: The average impact of risk occurrence cause i

R_{ij}: The R of risk occurrence cause i in stage j

N_{ij}: The number of respondents for risk occurrence cause i in stage j

N_i: The number of respondents for risk occurrence cause i

Table 2 Important Risk Occurrence Cause

No	Risk occurrence cause
1	A203.The collapse of the ground seems to happen in the construction site
2	A402.There are dangerous material to be used and kept
3	A701.Damage because of the crash and the falling down
4	C101.Inappropriate contract term to the content of construction, delay seems to happen
5	C102.Inappropriate contract term to the content of construction, cost overrun seems to happen
6	C103.The estimation is less than actual amount, but can not be claimed
7	C602.Because the description of contract documents is insufficient, the interpretation of the scope of work is different between the client and contractor
8	E101.The noise, the vibration, and the dust are troubled to neighbours
9	E201.The responsibility of the industrial waste is asked
10	E401.The large amount of traffic around the site, the disaster to third

	party seems to happen
11	E403.The collapses of heavy equipment, scaffold, steel structure, and formwork seem to happen
12	E902.Because the understanding is not obtained from the neighbours, the work time and work method are restricted by the agreement
13	F701.Because a lot of openings in the building the accident like falling happens
14	F708.The plan is forced to change due to the incompleteness of scheme on the way of execution
15	F903.The construction can't be processed on time due to the late approval of working drawing
16	Ga104.There is incompleteness in working drawings, the check system is not enough in the site
17	Ga206.Take time to keeping of the test data, photograph, and test result
18	Gb101.The human allocation and the support of headquarter are not enough as require
19	Gb102.Various conditions of the site are not considered, the headquarter demands the same profit improvement
20	Gb202.The management of the subcontractor is a weak (e.g. bankruptcy)
21	Gb204.The decrease in the quality is not permitted as for the deficit contract
22	Ha201.The improvement of the quality becomes a problem by workman's skill
23	Hb6.Because the fact of the site is not understood by the subcontractor with low mobilisation ability, the situation of the workers is difficult to handle
24	Hc101.The priority of concept is insisted by the designer makes the problems of construction, structure, finish and maintenance, etc.
25	Hc202.There is no clear answer from the designer due to the lack of the detail drawings
26	Hc4.The working drawings and materials cannot be appropriately approved due to the shortage of management capability of design supervisor
27	Hc501.A lot of design changes with late instruction from designers in construction
28	Hc601.Excessive construction accuracy is demanded by the designer
29	Hd301.There are a lot of nominated subcontractors from the client and the designer
30	Hd401.The increase of the cost by the design change cannot be reflected in the change order
31	Hd601.The communications between client and designer are bad
32	Hd901.The client has an excessive demand for the grade

EXTRACTION OF IMPORTANT RISK OCCURRENCE CAUSES

In order to extract the risk occurrence causes not biased to the importance for each risk result in the building project, the risk occurrence causes with the R value in the top 10 of each risk result were brought together (see Table 2). In the following, the decision support system in risk management is proposed to these 32 risk occurrence causes in Table 2. The principle is to keep the independence among these risk occurrence causes.

By comparing the distribution of these 32 risk occurrence causes with the distribution of Figure 3, the average probability concentrates on [0.35, 0.8], and the average impact concentrates on [0.4, 0.8]. That means the risk occurrence causes with the consensus are settled to the upper right of the two-dimension. One of the main purposes of the risk strategies is to change the risk occurrence causes located on the upper right to the lower left (Marshall, 2001). Therefore, it means that the excellent risk strategy can reduce the probability and the impact of the risk occurrence causes at the same time. The decision support system is necessary to select such risk strategies.

DECISION SUPPORT SYSTEM

One of the main purposes of the decision support system is to support the selection of a better alternative for the decision-maker. However, Arai (1998) claimed that it is very difficult to clearly separate the process of "Making the alternatives" from the process of "Selecting from the alternatives" in decision making. In this research, "Making the alternative" and "Selecting from the alternatives" in user's decision making are supported in the dialogue mode by a comprehensible analysis process. And, the framework of the decision support system in risk management was proposed from two viewpoints of the risk data search and risk analysis as written below (see Figure 5).

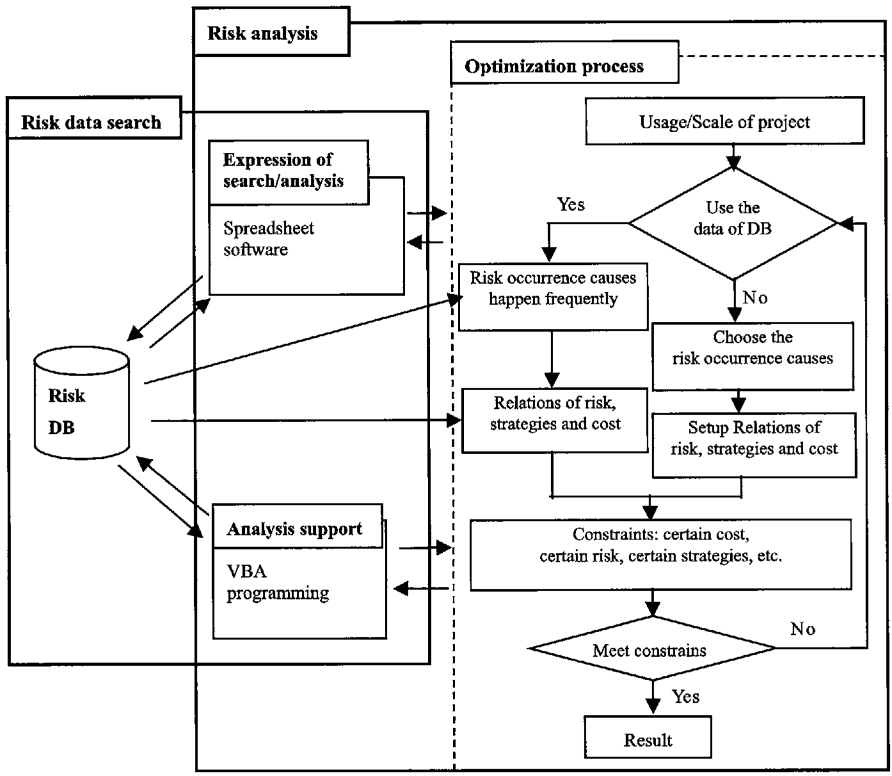

Figure 5 The Framework of the Decision Support System

Risk Data Search System

The system of risk data search is composed in three parts, which are the "risk data base", the "analysis support", and the "expression of search/analysis". For the decision support system to be used easily on the jobsite, the spreadsheet (for instance, Microsoft Excel) is mainly adopted as the interface for the expression of search and analysis. The data is retrieved from the database by the analysis support, which was designed by the VBA (Visual Basic for Application Edition) programming, and the result is shown on the spreadsheet in a dialogue mode. The risk data retrieval is divided into hierarchies. Moreover, these hierarchies are linked mutually. First, some elements of risk occurrence causes concerning the project are retrieved. For instance, risk occurrence causes often generated for some project types can be selected from the elements of project usage, project scale, and project location, etc. And, possible risk results and the value of the risk reduction are presented by the risk strategies, which often used for these risk occurrence causes.

Also, other risk occurrence causes which relate to these risk results can be displayed according to user's requirement In addition, the scenario of the trade-off of the risk in the project is simulated from the relations among the risk of each risk occurrence cause, the cost of the forecast damage, the risk strategies, and the strategies cost, etc. by the selection in a dialogue mode. In other words, a primary/qualitative analysis concerning each risk occurrence cause in the project risk is proceeded according to historical data.

Risk Analysis System

The main purpose of the risk analysis system is to do quantitative analysis in the project risk. The system of risk analysis is composed in three parts, which are the "process of optimisation", the "analysis support", and the "expression of search/analysis". The result of the analysis is expressed on the spreadsheet as mentioned above. The computational algorithm of the data exchange with the data base in the optimisation process is supported by mainly using the VBA programming in the analysis support. Optimisation is divided into two levels. The first level of optimisation is called partial optimisation, which is by the selection of risk strategies against individual or multiple risk occurrence causes. The second level of optimisation is called total optimisation, which is by the combination of constrained conditions with the project risk. The optimisation process is a process for which the alternative is made by certain constrained conditions. First, the data used for the analysis should be identified by the elements concerning the project. For instance, the elements may be the project usage, the project scale, and the project location, etc. And, the risk data about risk occurrence causes, often generated for such project type, should be inputted.

Next, the user selects whether to use historical data of data base. And, the user should judge whether to use relations among the risk occurrence cause, the cost of the forecast damage, the risk strategies, and the strategies cost, etc. from the data base, or to reset the data directly. In addition, the constrained conditions concerning the project and the objectives of the analysis are set. For instance, the risk strategies may be chosen under the condition of certain cost or the necessary cost in order to keep certain level of project risk, etc. From quantitative analysis, whether the results meet the requirements are judged based on these conditions. Finally, the alternatives, which meet the constraints, are presented for the user's decision making can be supported.

CONCLUSIONS

In this research, the fundamental data of the project risk was analysed from some viewpoints through the investigation of actual situations of the construction site. And, the realities of risk management in Japan was clarified based on the analysis.

In addition, the important risk occurrence causes have been extracted for the decision making system by examining the ranking of each occurrence cause in each stage and risk result.

As a result, the following four achievements were obtained.

1) The fundamental data concerning the project risk in the construction phase of the building project was collected, and analyzed.

2) The criteria of accumulation contributing ratio and distance were proposed as a method that the important risk occurrence causes of project can be extracted.

3) The current state of the project risk and the realities of risk management in the building project were clarified.

4) The framework of decision support system in risk management was proposed.

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Innovation by SMEs in the European Union Construction Industry. Some Outstanding Issues for Investigation

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ABSTRACT

Although innovation has become a major component of European Community (EC) industrial policy, there are concerns that it does not take account of either the particular circumstances that pertain in the construction sector, the influence that the construction sector has on the costs and competitiveness of other economic activities within the EC, or the essential role played by mainly small and medium-sized enterprises (SMEs) in promoting innovation in the construction process. CONSTINNONET is an EC-funded project, which aims to promote innovation in the EC's construction sector. The main technological objective is to increase the input-output ratio of Research and Technological Development (RTD) by SMEs. The approach has been twofold: to find instruments that best promote the successful generation of and implementation of new ideas by SMEs; and to find instruments that best promote the successful dissemination and use of those instruments. The first set of instruments has been judged in terms of the speed and risk of their innovation outputs, and in terms of the ease with which they can be spread and used in the EC. The second set of instruments has been judged primarily in terms of the amount and nature of SME participation in the EC's Framework Programmes for RTD. The approach has focussed on working with SMEs to ensure that the project is conducted from their viewpoint and that the results will be relevant to them. This interim paper presents practical recommendations on the actions that need to be taken in order to achieve the twin objectives of better innovation and improved technology transfer.

Keywords: Construction; Europe; Innovation; SME; Industrial policy

INTRODUCTION

The European Council's strategic goal for the first decade of the 21st century set at its Lisbon Summit in March 2000 is for the European Community to "become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion." Innovation is a necessary part of the strategy to achieve that goal. This includes innovation in the construction industry, on account of the fact that it is the largest industry in the EC; that it imposes significant overhead costs on the activities of all EC activities; and because of its apparently poor innovation record.

According to data provided by the European Commission (1997), the gross output of the construction industry in 1996 amounted to 750 billion Euro, which represented approximately 11% of the Community's GDP and 5.6% of its value added. It employed 8.8 million people in construction, or some 7% of the working population. In fact, more than 26.4 million workers in the EC depended, directly or indirectly, on the construction industry. That is, the 8.8 million jobs in construction, plus the 0.8 million jobs in design, gave rise directly to 2.5 million jobs related to construction products, and indirectly to 14.3 million jobs in other service sectors. Furthermore, construction and construction-related issues, such as maintenance, energy consumption, the quality and overall sustainability of the working environment, impose significant overhead costs on all sectors of the EC economy.

These facts are reflected in the Commission's proposed goals for a Community construction industry strategy:

- the maintenance and, if possible, improvement in the competitiveness of the EU construction industry; and

- by improving the competitiveness of the construction industry, having a positive influence on other industrial sectors, as well as on employment and growth.

In this context, innovation in construction appears to be too low. For example, research and technological development (RTD) expenditure by construction firms – a typical measure of the industry's capacity to innovate – was approximately 0.1% of construction GDP in 1998, whereas total research and development expenditure in the EC-15 countries was 1.86% of total GDP. Furthermore, there were fewer innovators among construction firms in 1996 than there were in the manufacturing sector (SPRU, 2001). The problem is thought to be especially acute amongst construction SMEs, who play a major role in the industry, accounting for more than 97% of some two-million construction companies in the EC. However, the extent of the problem and its nature remain open to debate and further research.

'Promoting Innovation in Construction Industry SMEs' (CONSTRINNONET) is a European Union funded project which aims to "increase the input-output ratio of research and technological development (RTD) by construction SMEs in the EC".

The project plan sets out three main courses of action, the objectives of which are to:

- identify instruments which best promote innovation by construction SMEs;
- identify instruments which best transfer innovation ideas and knowledge about innovation to and from construction SMEs; and
- develop a generic EC model of innovation in the construction industry, which can be used to close the gap between EC innovation policy and the activities of construction SMEs.

Each course of action will include workshops and interviews in different regions of the EC, viz. Belgium, Finland, France, Greece, Spain, and the UK. These will involve research centres, technology centres, technology transfer centres, national funding agencies, SMEs and various other bodies. It is anticipated that the objectives of the project will help the Community to achieve its strategic goals for the construction industry and the economy.

The objectives of this paper are threefold:

- to present a conceptual framework for collecting and analysing data on innovation by construction SMEs;
- to use this to analyse the results of some of the studies that have already been conducted in this area; and, thus,
- to raise some of the issues that require further investigation.

CONCEPTUAL FRAMEWORK

The terrain of innovation

In order to understand the innovation problem in construction it is necessary to understand the construction industry. The construction industry in its broadest sense includes all those activities that contribute directly to the production and maintenance of the built environment (see, for example, Carassus, 1999 and European Commission, 2000). It includes briefing, design, site-based construction, and facility management. The conventional and narrower definition of the construction industry – the set of firms that build or demolish structures – represents a subset of these activities (see, for example, NACE Rev. 1).

Figure 1 presents the key actors, their main types of interaction, and the major framework conditions in the construction industry. The actors include building materials suppliers, machinery manufactures, building component manufacturers, sub-assemblers (trade speciality and installers), developers and facility assemblers (or general contractors), facility/building operators and managers, facilitators and providers of knowledge/information, providers of complementary goods and services, and institutional environment actors.

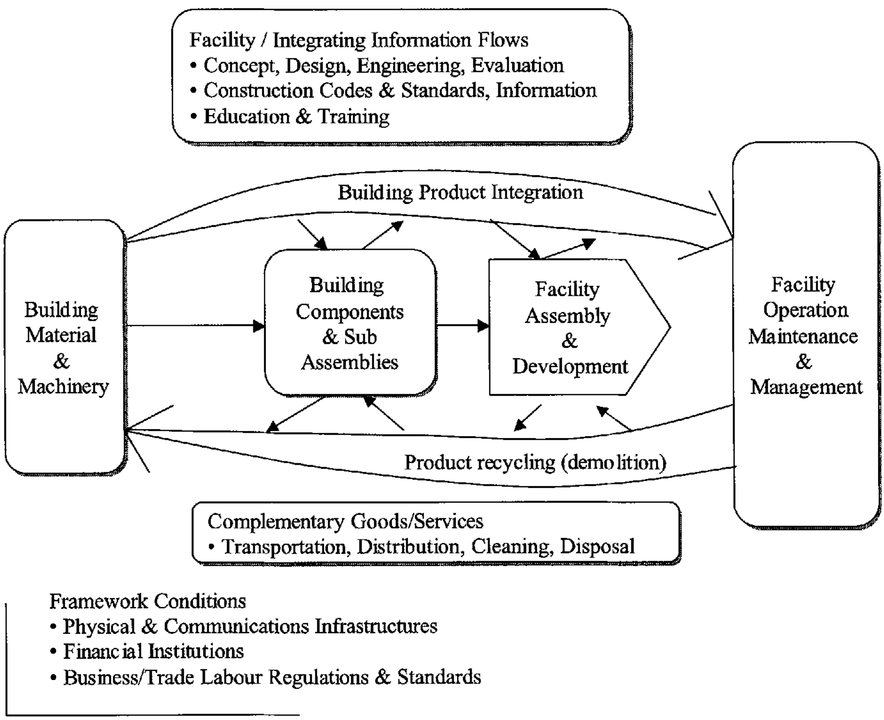

Figure 1 Key agents, major types of interactions and framework conditions in the construction industry (Manseau, 1998. In Manseau *et al*, 2001)

The two main types of interaction are building product integration, and product recycling (including demolition).

Innovation by construction SMEs occurs within the context of this complex system of interacting sub-systems and processes. It occurs within the context of the technical processes of building product integration and product recycling. It occurs within the context of the social organisation of those processes; and it occurs within the institutional structure of the industry, which provides the context for the organisation of production. It also occurs within the context of firms, and their specific processes and social structures. A high level of dynamism and a high level of uncertainty accompany this complexity, with specific consequences for innovation (Winch, 1996).

One of the unique characteristics of construction is its site-specificity. This means that any project has a high number of unique problems which need to be solved throughout its term, and which create high levels of uncertainty (Winch, 1996). In the pre-construction (planning) stages, it must consider interaction with existing faculties; satisfy urban planning procedures; and meet the client's requirements. On-site assembly work is inherently dynamic. Natural conditions – geological and climatological – generate uncertainties; building components vary in character – from low-tolerance and simple components such as bricks to high-tolerance and complex components such as advanced engineering services installations – and the skills required for their integration into the building product; and the general complexity of building product integration. These difficulties are compounded by and help to explain the temporary nature of the project organisation.

Project organisations consist of two types of actor – skill containers (e.g. architectural practices, trade contractors) and project coordinators (e.g. project managers, construction managers, main contractors). The trend since the late 1980s in UK construction and engineering, at least, has been toward the increasing separation of these two roles both within and between firms. The job of project co-ordinators is to mobilise the resources of firms towards the immediate market demand and to manage risks.

Because of their site-specificity, construction projects are inherently innovating – even if the construction industry is not – and the production (project information) flow consists of a process of uncertainty reduction through time. Where this process of uncertainty reduction is shared between firms, as in construction, collaboration is required. Winch (1996) identifies two types of organisational strategy: the industrial strategy, which places emphasis on the effectiveness of the process and the financial strategy which places emphasis of the circulation of capital in pursuit of narrow economic efficiency.

The institutional structure of the industry provides the wider context for the project organisation of construction. This includes overlapping international, national, regional and industry-specific structures. Its main features are the relationships between the main actors within the activities of conception, construction and control; and the regulation of their industry by third parties. The vast majority of construction services are procured through competitive markets, and the frequency of repeat business is low (with the exception of maintenance work). In the EC, the state is the prime mover in developing the institutional structure of the construction industry. It does this in two ways – as regulator and client. Indeed, in most EC countries, the state and its agencies account for up to 50% of construction demand (Winch, 1996). Institutional structures vary across countries. Amable *et al* (1997) have identified four different "social systems" amongst highly industrialised OECD countries, which vary according to the role of the state: the market-driven system (UK), the government-led system (France), the social-democratic system (Finland), and the meso-corporatist system (Japan)

Innovation also occurs within the context of firms. The type of innovation undertaken, and the different organizational factors which are brought into play depend to a significant extent on the environment in which the firm is operating. For example, it will depend on whether the firm is engaged in conception, construction or control; building product integration or product recycling; and public or private works. In some cases – especially those involving large firms – this will mean that the project organisation will take the form of a matrix, with the central product form overlying a series of firm-based functional forms. The purpose of the project organisation will depend on the institutional system.

The Concept of Innovation

Innovation involves a process of creating (inventing), developing and implementing a new idea (Van de Ven *et al*, 1999; Barrett *et al*, 2001). At the very least, the idea is new to the firm. In some cases it is new to the world. An idea has been implemented if it has been introduced on the market (technological product innovation), used within a production process (technological process innovation), or used to reorganise an institution, such as a firm or a project team (organisational innovation). However, it is not usually considered to be innovative unless it results in a significant and measurable change in output, such as increased productivity or sales (OECD, 2000).

Technological innovations are the usual focus for innovation studies, largely on account of their impact on performance and their measurability. They comprise technologically new products (or major product innovations) and processes and significant technological improvements in products and processes (or incremental innovations) (OECD, 2000). Although organisational (or administrative) innovations are not usually the focus of innovation studies, they play an important part in facilitating technological innovation (see Atkin, 1999).

The Process of Innovation

The process of innovation comprises "activities which actually, or are intended to, lead to the implementation of technologically new or improved products or processes." (OECD, 2000) Research and experimental development (R&D) is just one of those fields of innovative activities, and "comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, and the use of knowledge to devise new applications" (OECD, 1993). Besides R&D, the OECD 2000 distinguishes six other fields of innovative activities: tooling-up and industrial engineering; manufacturing start-up and pre-production development, marketing for new products, acquisition of disembodied technology, acquisition of embodied technology, and design. The actual mix of activities depends on the nature of demand and on supply factors, including project organisation.

Many attempts have been made to construct models that shed light on the process of innovation. Figure 2 is a simple, linear model of innovation. It suggests that there are three basic, and strictly sequential, innovation activities: research, development, and implementation.

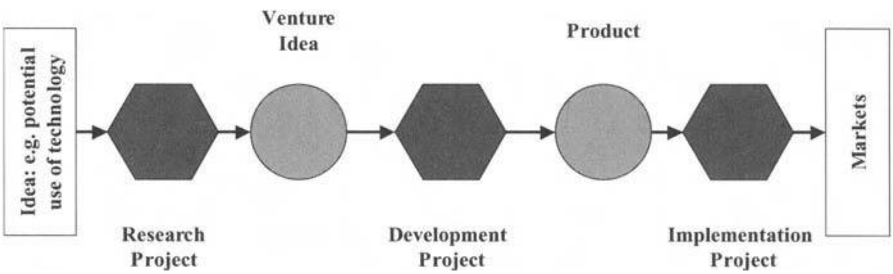

Figure 2 Linear description of innovation

An alternative approach is the "chain-link model" of Kline and Rosenberg, shown in Figure 3. This also conceptualises innovation in terms of interaction between market opportunities and the firm's knowledge base and capabilities. However, in this model there is a feedback between all parts of the process. Moreover, "in the chain-link model, research is viewed not as a source of inventive ideas but as a form of problem-solving, to be called upon at any point. When problems arise in the innovation process, the research system takes up the difficulties which cannot be settled with the existing knowledge base, and so extends it if successful. It is an adjunct to innovation, not a precondition for it." "The point to be noted is that innovation is a complex, diversified activity with many interacting components."

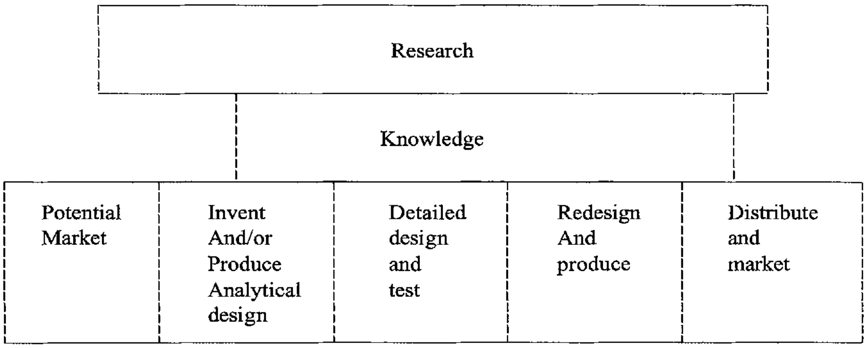

Figure 3 The chain-link model of innovation (OECD, 2000)

LITERATURE SURVEY

The EU's strategies for innovation are based partly on the results of two Community Innovation Surveys (CIS). These surveys have gathered information on technological innovation activity in all European member states. Although firms in the manufacturing sector have provided most of this information, firms in the construction industry have also provided some information.

A recent report by SPRU (2001) – a draft of which has been seen by the authors – presents an analysis of technological innovation in the Construction and Building Materials sectors of the Construction Industry based on UK businesses' returns to the second CIS. This survey was carried out in 1997/8, with reference to the situation in 1996. The authors advise that data for other Member States has not been made generally available, so they have not been able to perform any international comparisons. The report compares the results for Construction and Non-Metallic Mineral Product Manufacturers, the main materials suppliers to the construction sector with those for UK manufacturing as a whole. The analysis indicates that the construction industry – as represented by construction firms and building materials firms – is less innovative than manufacturing, both in terms of its output and its innovation inputs. It has fewer innovators; a smaller proportion of total turnover in new product areas; and R&D – a measure of the capacity to innovate – accounts for a smaller proportion of its total innovation costs. Nevertheless, the analysis also indicates that in terms of innovation inputs the industry is, in some cases, more innovative than manufacturing. It shows that innovation intensity (percentage of turnover spent on innovation) is much higher in building materials suppliers than the manufacturing average, although it is much lower in construction firms. Furthermore, although R&D expenditure is relatively low in both the Construction and Building Materials sectors, the proportion of total costs devoted to the acquisition of machinery and equipment is much higher.

The authors also analysed data on the context of innovation. They found that construction firms' sources of information for innovation activities are like those for manufacturing firms: the enterprise itself and clients. In contrast, the most important sources for the construction firms are its suppliers, health and safety regulations, and clients. They also found that construction firms have a lower propensity to enter into co-operative arrangements on average when compared to manufacturing. Where such arrangements are in force, customers, suppliers and other enterprises within the group are preferred partners. For materials suppliers, universities and other higher education establishments are important partners too. Indeed, materials suppliers make more use of public schemes, especially ones concerned with collaborative research.

Why is technological innovation in the construction industry so low? According to Atkin (1996), which is perhaps the most comprehensive report to date on innovation in the EC construction industry, the key problem is that technological innovation is constrained by the organisation of the construction process. On the basis of 16 case studies – including organisations involved in commissioning, designing, constructing, managing and maintaining, supplying components and supplying services to the construction and maintenance of, the built environment across EC – he reports that the organisation of the construction process does not make sufficient use of suppliers' (specialist contractors and component suppliers) expertise, many of whom are SMEs. The report adds that, in some cases, suppliers are not involved more in the construction process – organisational innovation is inhibited – because they are perceived to be incompetent, while, in other cases, there is simply a lack of awareness of their capabilities.

Miozzo and Ivory (1998) provide a different perspective on the problem. On the basis of 13 case-studies of innovation by construction SMEs (including 10 contractors) in NW England, they find that it is the structural characteristics of the industry (high concentration ratio; large number of small sub-contractors), rather than either the incompetence of SMEs or a lack of awareness of their capabilities *per se*, which best explains the organisation of construction and the corresponding lack of technological innovation. The key constraint on technological innovation is the power that downstream organisations (large contractors and their clients) have in the UK to transfer risk up the supply-chain.

However, there appear to be significant international differences in the relationship between the structure of the construction industry and the allocation of risk. As Winch (1996) explains, risk allocation in construction has two forms: horizontal shedding and vertical shedding. He demonstrates that the former is characteristic of the French system of construction while the latter is characteristic of the UK system, although the construction industry in both countries displays the same basic structural characteristics. Under the UK system, risks end up being carried by organisations that are ill-equipped to do so (e.g. under-capitalised trade contractors and labour-only gangs). He adds that these forms of risk allocation are closely related to the type of organisational strategy employed in the different systems. In France organisational strategies are "industrial", placing the emphasis on the effectiveness of the process, and therefore favouring horizontal shedding of risk. In the UK the strategies are "financial", placing the emphasis on the circulation of capital in the pursuit of narrow economic efficiency, and therefore favouring vertical shedding of risk. In short, the problem is embodied in the construction system.

Atkin documents many other organisational constraints on technological innovation. It reveals that the organisation of projects inhibits innovation in design, because designers are either unwilling or unable to take risks; that its attitude toward suppliers perpetuates traditional practices and *ad-hocracy* within construction firms, which discourage investment in RTD, especially by component and materials suppliers, and investment in other innovation activities within the industry, such as networks; and that it fails to engage adequately the interests and support of customers.

So how do these conditions impact on innovation by SMEs? The study of innovation by construction SMEs is in its infancy, partly because of problems in measuring innovation in SMEs, where formal RTD is unusual and the concept of innovation is rarely articulated. Barrett *et al* report the results of one of the few studies undertaken to date. The report is based on seven case studies of *small* construction firms, including three consultants and four contractors, in NW England over an 18-month period between 1999 and 2001. The authors report that there are four critical factors of successful innovation by small construction firms: 'business strategy / market positioning', 'organization of work', 'technology', 'people', and the firm's business environment.[1] These factors constitute a system, which takes a variety of forms, characterized by a firm's relationship with its clients, from "single-project, cost-orientated relationships" to "multi-project, value-orientated client relationships. These environmental conditions give rise to different 'modes of innovation'. In the latter case, the scope for technological product innovations is much higher in the latter case than the former, where the emphasis tends to be on organisational and technological process innovations aimed at reducing risks. Indeed, the authors advise that these modes of innovation are appropriate in the circumstances, reflecting the effectiveness of the owner-managers role in developing a strategy to balance the firm's capabilities with its market

[1] According to the framework presented in the previous section of this paper, "business strategy / market positioning" is an aspect of a firm's organization. "People" (the firm) is an aspect of both a firm's organization and its technology.

opportunities. In some cases it is appropriate to employ an industrial strategy, but in most cases it is appropriate to employ an industrial strategy.

OUTSTANDING ISSUES

This paper has outlined a conceptual framework for collecting and analysing data on innovation by small construction firms in the EC. The framework defines the innovation terrain, innovation, and the process of innovation. These elements constitute a basic system of construction innovation, which can be developed and revised in the light of further research.

The paper also reviewed the findings of previous work on innovation in the construction industry. In summary, SPRUs' analysis of the data supplied by the second CIS survey of innovation provides an indication of the extent and nature of innovation and innovation activities. It finds that technological innovation is low, especially among construction firms; that technological process innovation tends to take the form of bought-in equipment, rather than being generated internally; and that construction firms, as assemblers of construction product integrators, tend to rely solely on external sources of information, with the onus for technological innovation being placed on the materials suppliers and equipment manufacturers, as shown by their broader innovation networks.

Reports by Atkin (1996) and Miozzo & Ivory (1999) help to explain why technological innovation is low. Although construction projects are inherently innovative on account of their site specificity, both reports suggest that the organisation of projects, and the inherent management of risks, could be better. Atkin, for example, finds that the organisation of projects makes insufficient use of suppliers' (specialist contractors and component suppliers) expertise; that it inhibits innovation in design, because designers are either unwilling or unable to take risks; that its attitude toward suppliers perpetuates traditional practices and ad-hocracy within construction firms, which discourage investment in RTD, especially by component and materials suppliers, and investment in other innovation activities within the industry, such as networks; and that it fails to engage adequately the interests and support of customers.

Winch (1996) argues that the extent of the problem varies systematically from one country to another. He suggests that in the UK, where the favoured organisational strategy is to shed risk vertically, technological innovation is lower and/or less effective than in France, where the favoured organisational strategy is to shed risk horizontally. This finds some support in Barrett et al (2001), which provides evidence that traditional methods of organising projects discourage technological product innovations by small construction firms aimed at maximising return-to-risk, and encourage organisational and technological process innovations aimed simply at reducing risks.

All of the studies suggest that the industry should make better use of and improve its technological capabilities. The challenge is to identify and implement new organisational forms that can support technological innovation. In its role as regulator and client, national government is an important actor. It can encourage formal and informal networking between the organisations involved in the creation, transfer and implementation of technologies. It can fund more research on the relationship between networks of SMEs and technological innovation. The identification and dissemination of effective networks for SMEs is one of the main objectives of the CONSTRINNONET project. It is clear from the research undertaken by Barrett et al (2001) that if these networks are to be effective have to be in sync with the capabilities and market opportunities of SMEs.

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MULTIPLE CRITERIA PROPERTY E-BUSINESS SYSTEM

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ABSTRACT

Abstract. *The analysis of e-business and decision support systems used in property which were developed by practicians and researchers from various countries helped the authors to create Property E-Business (PEB) System of their own. Capabilities to use the PEB system in practice are: property valuation in various aspects (i.e. determination of market value, value in use, investment value), valuation of factors affecting value of property (i.e. valuation of property location, property depreciation), determination of the highest and best use of a property, etc. Presentation of information are in conceptual (digital, textual, graphical, photographical, video) and quantitative forms. The more property are investigated, the greater is the possibility to achieve a more rational end result. Strong and weak sides of investigated property are given an analysis. Facts of why and by what degree one version is better than the other are also established. All this is done basing oneself on conceptual and quantitative information. For instance, it is possible to make a detailed analysis of strong and weak sides of property under investigation following the calculated criteria, criteria significances, priorities of property, level of utility degree and market value of property under valuation.*

THE MAIN ENVIRONMENTAL FACTORS INFLUENCING E-BUSINESS EXISTENCE

With the aim of correctly understanding the role of the e-business and its development prospects, it is necessary to investigate the main environmental factors influencing its existence. Various economic, legal, social, technological and political factors force the traditional business one way or another to transform into e-business. Connected to different changes such as the increased qualifications of the workforce, minimization of state regulation, reduction of state subsidies, the increased importance of ethic and legal issues, tough competition, global economy, regional trade agreements, cheaper manpower in certain countries, frequent and significant changes within the markets, the increased power of consumers, accelerated moral depreciation of technologies, the increased importance of innovations and modern technologies, it has become necessary to create e-business.

The Internet, information technologies, e-business are being developed rapidly in well-developed countries globally, especially in the United States of America. The huge amount of information is being gathered and knowledge bases are being formed, based on the highly-skilled specialists who are selling their experience and knowledge through the Internet at a relatively low price. There are a lot of various Internet services on offer such as travel and tourism services, employment placement and the job market, property, trading stock online, cyberbanking and personal finance, auctions, online publishing, knowledge dissemination, etc.

Many e-business systems are seeking to find out how to make the most economic decisions, and most of all these decisions are intended only for economic objectives. Alternatives under evaluation have to be evaluated not only from the economic position, but take into consideration qualitative, technical and other characteristics as well. For example, an analysis of property is usually performed by taking into account economic, quality such as architectural, aesthetic, comfort, infrastructure, technical, legal, technological, social and other factors. Alternative solutions allow for a more rational and realistic assessment of economic, technical conditions and traditions and for more satisfaction of different customer requirements. The Internet and information technologies application also enables to cut down on project costs.

Competition within different fields of the e-business is becoming stronger and stronger, and involves more and more business people. In order to survive in such tough competition conditions, it is necessary to make every effort and aim at creating and offering something better than your competitors. For example, enhancement of the quality of services and reduction of prices, expansion of markets, flexibility in responding to fluctuations of the demand and supply in the market, extension of the range of commodities and services, strengthening of relations with the manufactures and suppliers of necessary commodities and services, seeking for greater confidence of consumers must be included. This would allow the e-business to satisfy the needs of potential consumers and increase the number of the loyal and regular clients.

VALUE OF ARTIFICIAL INTELLIGENCE

A major value of employing intelligent agents with internet applications is that they are able to assist in search of alternatives, finding out of alternatives, analysis of alternatives and selection of most efficient ones. They save time by support decisions about what is relevant to the consumer. Consumers need new ways to minimize the time spent on routine tasks such as search of alternatives; finding out of alternatives and making of comparative tables; analysis of alternatives and selection of most efficient ones, so that they can devote more time to professional and other activities. These intelligent agents perform the tedious, time-consuming, and repetitive tasks of searching alternatives, retrieving and filtering information, delivering it back to the user, and analysing alternatives. There is a need for increased support for tasks performed by intelligent agents, especially in the decision-making area. Timely and knowledgeable decisions made by these intelligent agents greatly increase e-business effectiveness.

E-BUSINESS AND COMPARISON SHOPPING

E-business describes the processes of buying and selling of products, services and information, servicing customers, collaborating with business partners, conducting business transactions via the Internet. For example, consumers' shopping activities, on the Internet, can be analysed through the processes of: initial requirement determination, search and comparison of alternative products or services, placing orders, paying bills, deliver items, inspecting quality, and after-sale service support.

Many systems of electronic business are processing and submitting only economic information for decisions, and applying economic models. Alternatives under consideration have to be evaluated not only from the economic position, but take into consideration qualitative, technical and other characteristics. For example, the analysis of property is usually being performed by taking into account economic, quality (architectural, aesthetic, comfort), infrastructure, technical, legal, technological, social and other factors. Therefore, the efficiency of e-business may be increased by applying multiple criteria decision support systems.

One of the major problems in e-business is to find what you want. The number of alternative products and services on the Internet are in the thousands. How can customers find the rational products and services on the Internet? Once product or service information is found, the customer usually wants to compare alternatives. There are five types of aids to comparison shopping:

Search on hypertext files by agents. Agents can find alternatives with relating information (list prices, and other characteristics), seller's address, and search for minimally priced products.

Search alternatives on databases. Many electronic catalogues built using a Dynamic Web-based Database Management system exist today. The software agents are computer programs that help users to conduct routine tasks, search and retrieve information, support decision making, and act as domain experts without human intervention. Software agents can find products and make direct comparisons between products from the database.

1. Alternative search and tabular comparison. Alternatives can be found and carry out tabular multiple criteria comparisons.

2. Comparison of alternative products and services from multiple malls.

3. Search and multiple criteria decision making. The multiple criteria decision making methods and multiple criteria decision support systems are used in this type of e-business comparison shopping.

A BRIEF REVIEW OF PROPERTY E-BUSINESS SYSTEMS

Today there are a great number of directories, and e-business systems, worldwide, related to property: such as www.ired.com, www.cyber-homes.com, www.comspace.com, www.assist2sell.com, www.eloan.com; www.iown.com, www.homescout.com; http://realestate.yahoo.com, www.mapquest.com, http://realestate.yahoo.com, www.datatrac.net, www.realtor.com, www.replace.com, www.bankrate.com, www.eloan.com, www.quickenmortgage.com, www.rent.net, www.arcsystems. com, ASHI, Countrywide, CyberHomes, Digital City, DoItYourself.com, GetSmart, Home Advisor, Homebuyer's Fair.

These systems provide information and partially the following services: purchase, sale and lease of property; various consultations and information about purchase, sale and lease of property; detailed information on loans; help in searching for, reviewing and comparing alternative creditors, consolidation of debts, insurance services; settling down in a new place; advice of experienced buyers, sellers and leaseholders to inexperienced "rookies"; selection of dwelling-places or rehabilitation facilities such as sanatoriums, rehabilitation centres, old people's homes; acquisition, lease or leasing of pieces of furniture, audio and video equipment and other household items; information about the possibility of moving to a new place of residence; various searches and enquiries such as search property on lease on the basis of submitted information, search for a roommate; property and facilities management services; various advertisements; educational and instructional information.

A brief description of some of the services and information provided are as follows.

The property advertisements provide textual and video information, photographs, plans and maps of a locality. The systems provide potential buyers or leaseholders with the possibility of making a virtual visit to the selected property object. There is also information available for the purpose of becoming better acquainted with the analysed object and its surroundings. For example, with the aim of receiving additional information about settling in to a new place, the potential buyer or leaseholder may ask for possibilities of employment, furniture leasing, schools, kindergartens, and polyclinics.

After analysing the provided information, and with the purpose of clarifying certain issues, potential buyers or leaseholders may directly contact the property agent or the system employees by e-mail and receive the required information. With the aim of ensuring that the user's information is the latest, advertisements, and notices, are constantly updated.

Systems allow the users to compare loan options offered by different financial institutions. The systems provide conditions for analysing alternative loans during their life cycle and co-ordinate objectives both of the creditor and borrower with the aim of obtaining acceptable loan solutions for both parties.

There are also possibilities to settle accounts via the Internet.

Provision of information about insurance services such as title, hazard, liability, theft, partnership life, and insurance is made. The possibility of becoming acquainted with different types of insurance offered is provided. Explanatory comments about the necessity of the insurance, a description of its constituent parts and the insurance contract's procedure, are also given.

The possibility of becoming acquainted with the information provided by experienced buyers or leaseholders such as the period of time fixed for buying or leasing a flat or house, the fastest and cheapest way of carrying out repairs, basic rules to be learned by a lessor, comparative analysis of the purchase and lease, legal issues, insurance are available on the Internet.

Provision of information about the property buying (motives for buying a new flat or house, addresses of property agencies, and subsidised loans) and selling (addresses of property agencies, information about dependence of the market value of property on the status of neighbours, location of the object, its exterior and condition, infrastructure, air contamination, and prestigious district) issues are provided on the Internet.

Advice and information about lease and planning of the property as well as moving and adaptation to a new place of residence, the most efficient way to lease the property are found via the Internet. About neighbours in a new place, how to take out a loan, preparations for moving to a new place, arrangements for removing furniture and other items, transport, and related taxes, removal vans and providing transportation services such as furniture, and cars, information about safe and secure furniture transportation, how to lease or purchase furniture, various household appliances, articles of art, how to protect or insure the leased property, how to adjust oneself to a new place and find a job may be found via the Internet. Also information is provided about qualification enhancement courses, how to take care of children in a new place such as schools, kindergartens, and other facilities, shopping facilities, leisure-time spending and entertainment opportunities, climate and other information are all available via the Internet.

Provision of various space management services. Systems provide information about various forms of space management: space organisation, workplace analysis, and removals; inventory compilation/updating e.g. space compilation/updating, stock compilation/updating, systems compilation/updating, room log compilation/updating, and disposition/space reserves; central services e.g. building security service, cleaning, snow-clearing service, upkeep of outdoor facilities, garden care, plant care in the building, pest control.

Provision of various technical management services. Systems provide information about various forms of technical management: maintenance, inspection, repair, equipment, emergency service e.g. gas, water, wastewater, heating, water heating, ventilation, cooling, electrical systems; lightning protection, lifts, conveyor and warehousing systems, automatic door and gate, security; central and building control, communication, cable and network, laundry and dry-cleaning systems, general building equipment, other equipment and systems; technical operations management e.g. house technician/caretaker, 24-h service and stand-by service, operation of the technical systems and centres, central control systems energy management .

Information about how to spend one's leisure-time. For example, a lot of information is available about cultural activities taking place in the neighbourhood, e.g. sport facilities, gardening opportunities, and work about the house e.g. facilities and work tools, planning of house repair works, maintenance of lawns and gardens, acquisition of instruments for out-of-door work, purchasing of plants and garden decorations; as well as for the renovation of the interiors is available. Information may be found about surrounding shops and available services, acquainted with prices of commodities and services and ordering them. For example, after entering the name of a certain item or service, the display will provide a list of the required items of services.

The direct presentation of property on a Web page does not provide the possibility for quick updating of provided information and hampers the search for the required information. Currently, information is most often stored in some database, e.g. Oracle, and when necessary it can be retrieved from the database and transferred onto a Web page. The storage of information in the database provides the possibility of presenting the data on various Web pages or compact disks and also to issue printed catalogues.

Very often the e-business systems process the received information statistically and present it in a generalised form. These statistical figures are required, for obtaining a general picture by categories of consumers and, if necessary, by efficiently responding to new trends developed within the property market.

ANALYSIS OF THE PROPOSED PROPERTY E-BUSINESS SYSTEM

Practical capabilities of the Property E-Business System

Following the mentioned and other ideas the authors have developed Property E-Business (PEB) System. Proposed PEB System can create value in next important ways: help customers assess their needs, identify suitable property to fulfil needs, compare and evaluate property, help customers evaluate the usefulness of the property in the after-purchase evaluation stage. In sum, proposed PEB System create greater convenience and better choices for buyers in the purchase process.

At present moment the developed PEB System allows performance of functions as follows: search of property, finding out of alternatives and making of comparative tables, alternatives multiple criteria analysis stage, the after-purchase evaluation stage.

A consumer may perform a search of alternatives from databases of different brokers (see Fig. 1). It is possible since the forms of data submission are standardized in a specific level. Such standardization creates the conditions to use the special intelligent agents performing search of the required property in various databases, and gathering information about them.

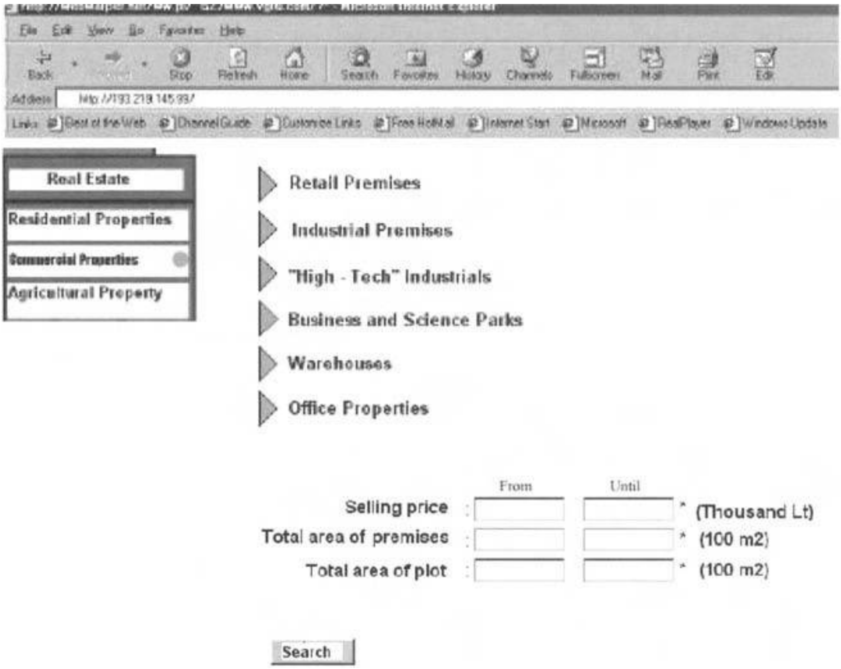

Figure 1 A consumer may perform a search of alternatives from databases of different brokers

Consumers specify requirements and constraints and the system queries the information of a specific property from a number of online brokers. The system performs the tedious, time-consuming, and repetitive tasks of searching databases, retrieving and filtering information, and delivering it back to the user. Results of search of a specific property are submitted in tables, which may include direct links to a Web page of a brokers. By submission such a display, the multiple criteria comparisons can become more effectively supported.

While going through the purchasing decision process a customer must examine a large number of alternatives, each of which is surrounded by considerable amount of information (economic, quality (architectural, aesthetic, comfort), infrastructure, technical, legal, technological, and other factors). Following on the gathered information the multiple criteria analysis are being caried out. Capabilities to use the Property E-Business System in alternatives multiple criteria analysis stage are:

- Property valuation from various aspects (i.e. determination of market value, value in use, and investment value).
- Multiple criteria analysis of alternatives and selection of most efficient ones.
- Valuation of factors affecting the value of property (for example, valuation of property location, property and depreciation).

The after-purchase evaluation stage. A consumer evaluates the usefulness of the property in the after-purchase evaluation stage.

As an example, solving the problem of determining the market value which include the highest price estimated in terms of money which the property would bring if exposed for sale in the open market, with reasonable time allowed in which to find a purchaser, buying with knowledge of all of the uses and purposes to which it was adapted and for which it was capable of being used of a property being valuated that would make it equally competitive on the market in comparison with the property already sold, a module of defining the utility degree and market value of a property was created. This was based on a complex analysis of all benefits and drawbacks of the considered property. In order to demonstrate the application of the above module and database, farmer's homestead estates were considered below, as a sample. Solving the problem of determining the market value of a farmstead a_1 being valuated, which would make it equally competitive on the market compared with the farmstead a_2 and farmstead a_3 already sold, a particular module and database of defining the utility degree and market value of a farmstead were created. The study was based on a complex analysis of all the benefits and drawbacks of the farmsteads considered. According to this module, the property utility degree and the market value of a property being estimated are directly proportional to the system of the criteria, adequately describing them and the values and significance of these criteria.

Database

Presentation of information in commercial property, dwellings, farmer's homestead estates and other types of property Web pages may be in conceptual (digital, textual, graphical, photographic, video) and quantitative forms.

Conceptual information means a conceptual description of the property, the criteria and ways of determining their values and significance (see Fig. 2).

Conceptual information is needed to make more complete and accurate valuation of the property considered. In this way, the system enables the decision maker to receive various conceptual and quantitative information on property from a database and a model-base allowing him/her to analyze the above factors and form an efficient solution.

Figure 2 Description of alternatives in photographic form

Table 1 Quantitative information presented involves criteria systems and subsystems, units of measurement, values and initial significance fully defining the variants provided

Criteria to be considered	*	Measurement unit	Significance	Alternative versions: Savanoriu Avenue	Gedimino Street	Algirdo street	Skroblu street	Liepu street
1. Selling price	-	Thousand Lt	100	186	130	157	125	173
Evaluation of the building								
2. Construction design	+	Points	3.5	0.80	1.00	0.85	1	0,7
3. Physical depreciation	-	Per cent	3.0	34	29	57	28	33
4. Functional depreciation	-	Per cent	2.5	42	52	37	51	47
5. Economic depreciation	-	Per cent	3.5	24	30	13	32	23
6. Number of auxiliary buildings	+	Units	4.0	1	0	0	0	1
Quantitative assessment of premises								
7. Total area	+	m^2	5.5	334	308	490	300	330
8. Number of sale rooms	+	Units	1.5	1	2	2	3	1
9. Area of sale rooms	+	m^2	3.3	130	218	230	200	155
Qualitative assessment of premises								
10. Interior	+	Points	4.0	0.60	0.55	1.00	0,56	0,8
11. Exterior	+	Points	2.3	0.80	1.00	0.75	0,6	0,8
12. The need for renovation	-	Points	3.5	0.70	0.50	0.15	0	0,6
13. Trading equipment	+	Points	4.5	0.75	0.00	1.00	1	0,75
14. Number of entrances	+	Units	1.0	1	2	2	0,7	0,7
15. Entrances with respect to the street	+	Points	5.5	0.95	0.60	1.00	0,5	1
16. Position of showcases	+	Points	4.5	1.00	0.50	0.90	1	0,9
17. Advertising possibilities	+	Points	4.0	1.00	1.00	0.90	1	1
18. Location with respect to parts of the world	+	Points	0.5	0.80	1.00	0.60	1	1
Assessment of communications								
19. Engineering communications	+	Points	3.5	1.00	1.00	1.00	1	0,36
20. Number of telephone lines	+	Units	1.5	1	2	1	3	1
21. Assessment of alarm systems	+	Points	5.0	0.00	1.00	0.00	1	1
22. Assessment of air conditioning	+	Points	2.0	1.00	0.25	0.75	0,29	0
Estimation of the place								1
23. Distance from city centre	-	Km	3.5	4	1	2	1	5
24. Public transport	+	Points	3.0	1.00	0.75	0.80	0,8	1
25. Distance from bus stops	-	Km	1.5	200	50	100	35	200
26. Car Park	+	Points	5.0	0.50	1.00	0.70	1	0,5
Other criteria								
27. Prestige of locality	+	Points	7.5	0.80	1.00	0.90	1	0,8
28. Assessment of market conditions	+	Points	6.5	0.95	1.00	0.95	1	0,95

A database was developed providing a multiple criteria analysis of property from economical, legislative, infrastructure, social, qualitative (architectural, aesthetic, comfort), technical, technological and other perspectives. This information is provided in a user-oriented way. To design the structure of a database and perform its completion, storage, editing, navigation, searching, and browsing, a database management system was used. Property E-Business System can use a number of interested parties (appraisers, vendors, brokers, property agents, investors, various organisations, enterprises, banks, other financial institutions and other creditors, insurance companies, buyers, courts, local authorities, state and their respective institutions) pursuing their specific needs as well as having different financial situations, educational levels and experiences.

The system of criteria is determined and the values and initial significance of criteria are calculated by experts. All this information can be corrected by interested parties, taking into consideration their goals and existing capabilities. The users striving to express his/her attitude towards these issues numerically may ascribe various significance values to them, which eventually will affect the general estimation of a property. Though this assessment may seem biased and even quite subjective, the solution finally made may exactly meet the requirements, aims and affordability of the user.

Model-base

Since the analysis of property is usually performed by taking into account economic, quality, technical, legal, social and other factors, a model-base should include models which enable will a decision maker to carry out a comprehensive analysis of the variants available and make a proper choice. The following methods developed by authors (models) are aimed at performing the next functions:

- A method and model for criteria significance establishment. A new method of complex determination of the significance of the criteria, taking into account their quantitative and qualitative characteristics was developed. This method allows calculation and co-ordination of the significance of quantitative and qualitative criteria according to the above characteristics.

- A method and model for multiple criteria analysis and setting priorities. A new method of multiple criteria complex proportional evaluation of the property, enabling the user to obtain a reduced criterion determining complex (overall) efficiency of the property was suggested. This general criterion is directly proportional to the relative effect of the values and significance of the criteria considered of property's efficiency.

- A model for the determination of property utility degree and market value. In order to find the price that will make a value property competitive on the market, a method of determining the utility degree and market value of property based on the complex analysis of all their benefits and drawbacks was suggested. According to this method the property utility degree and the market value of a property being estimated, are directly proportional to the system of the criteria, adequately describing them and the values and significance of criteria.

According to the user's needs, various models may be provided by a model-base management system. When a certain model (i.e. determining the initial significance of the criteria) is used the results of the calculations obtained become the initial data for other models (i.e. a model for multiple criteria analysis and setting the priorities (see Table 2)). Results of the latter, in turn, may be taken as the initial data for other models (i.e. determining property utility degree, determining property market value) without human interference.

A management system of the model base provides the user with a model base allowing him/her to modify the models available, eliminating those which are no longer needed and adding some new models linked with the existing ones.

In order to check the accuracy of the suggested system, the whole of its solution process has been more than once checked manually. The results of manual and computer calculations must match. All separate working stages of the system as well as all complex calculations have been co-ordinated with experts in this field - i.e. the essence of the calculations has been found to be in conformity with their logical reasoning. Owing to suggestions from these experts, useful changes have been introduced into the system. Checking by the experts is bound to the fact that universal decision making methods are not always suitable for specific tasks and can lead to gross errors or to bad results.

Table 2 Multiple criteria analysis of alternatives and selection of most efficient ones

Criteria to be considered	*	Measurement unit	Significance	Alternative versions				
				Savanoriu Avenue	Gostauto Street	Algirdo street	Skroblu street	Liepu street
1. Selling price	-	Thousand Lt	100	186	130	157	125	173
Evaluation of the building								
2. Construction design	+	Points	3.5	0.80	1.00	0.85	1	0,7
3. Physical depreciation	-	Per cent	3.0	34	29	57	28	33
4. Functional depreciation	-	Per cent	2.5	42	52	37	51	41
5. Economic depreciation	-	Per cent	3.5	24	33	13	32	23
6. Number of Auxiliary buildings	+	Units	4.0	1	0	0	0	1
Quantitative assessment of premises								
7. Total area	+	m^2	5.5	334	308	490	300	330
8. Number of salerooms	+	Units	1.5	1	2	2	2	1
9. Area of salerooms	+	m^2	3.5	150	216	230	200	155
Qualitative assessment of premises								
10. Interior	+	Points	4.0	0.60	0.55	1.00	0,56	0,8
11. Exterior	+	Points	2.5	0.80	1.00	0.75	0,6	0,8
12. The need for renovation	-	Points	3.5	0.70	0.50	0.15	0	0,6
13. Trading equipment	+	Points	4.5	0.75	0.00	1.00	1	0,75
14. Number of entrances	+	Units	1.0	1	2	2	0,7	0,7
15. Entrances with respect to the street	+	Points	5.5	0.95	0.60	1.00	0,5	1
16. Position of showcases	+	Points	4.5	1.00	0.50	0.90	1	0,9
17. Advertising possibilities	+	Points	4.0	1.00	1.00	0.90	1	1
18. Location with respect to parts of the world	+	Points	0.5	0.80	1.00	0.60	1	1
Assessment of communications								
19. Engineering communications	+	Points	3.5	1.00	1.00	1.00	1	0,56
20. Number of telephone lines	+	Units	1.5	1	2	1	3	1
21. Assessment of alarm systems	+	Points	5.0	0.00	1.00	0.00	1	1
22. Assessment of air conditioning	+	Points	2.0	1.00	0.25	0.75	0,29	0
Estimation of the place								1
23. Distance from city center	-	km	5.5	4	1	2	1	5
24. Public transport	+	Points	5.0	1.00	0.75	0.80	0,8	1
25. Distance from bus stops	-	km	1.5	200	50	100	55	200
26. Car Park	+	Points	5.0	0.50	1.00	0.70	1	0,5
Other criteria								
27. Prestige of locality	+	Points	7.5	0.80	1.00	0.90	1	0,8
28. Assessment of market conditions	+	Points	6.5	0.95	1.00	0.95	1	0,95
Priority of the project				**3**	**5**	**2**	**1**	**4**

CONCLUSIONS

The suggested system is a better online system to others, because the intelligent agents here compared a number of alternatives and different parameters. By applying this Property E-Business System it is possible to obtain quantitative and conceptual information that describes property from various aspects. The more alternatives investigated the greater the possibility to achieve a more rational end result. Strong and weak sides of investigated alternatives are given in the analysis. Facts of why and by what degree one version is better than another are also established. All this is done basing oneself on conceptual and quantitative information. For example, following such information and with the assistance of the Property E-Business System, the user is able to perform the following: property valuation in different aspects e.g. determination of market value, value in use, investment value, the valuation of special factors affecting value of property (for example, valuation of property location, and property depreciation) and the multiple criteria analysis of alternatives and selection of most efficient ones.

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A rating system for AEC e-bidding that accounts for rater credibility

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INTRODUCTION

Until recently e-commerce providers asserted how they would " revolutionize the way construction professionals conduct their business".[1] In April 2000 approximately $1 Billion had been invested in around 200 Architecture Engineering Construction (AEC) industry electronic commerce start-ups. In reality, the amount of transactions conducted in these new electronic market places turned out to be very low, and only a handful of them were still in business in February 2002. One possible cause of the AEC industry's slow adoption of electronic commerce is the lack of trust in the participants in electronic marketplaces. Electronic markets facilitates the search for new business partners, but AEC General Contractors, subcontractors, and suppliers are unlikely to do business with firms that are unknown to them. One solution to this problem is the creation of a rating system that gathers and displays information about the past performance of the market participants. The most well-known e-commerce rating system belongs to eBay, the largest and most successful Internet Auction provider, enabling transactions between private parties. eBay currently (Feb 2002) has over 30 million registered users. eBay's users buy and sell items that are varied, and often difficult to describe as well as evaluate. Trust is therefore a prerequisite for the transactions on eBay to take place. To foster trust, eBay has created a system by which the market participants rate each other after each transaction. eBay's success makes it interesting to investigate whether a rating system could support trust also in AEC e-markets. The eBay rating system is simple and intuitive to use. The problem is that all ratings weigh the same, implying that the system is built on the assumption that all raters are equally credible and trustworthy. This assumption may be valid in C2C auctions but we doubt that it applies to complex B2B transactions, such as AEC bidding. More sophisticated electronic commerce rating solutions have been developed incorporating features such as multiple criteria (e.g., Bizrate), network of

[1] See for example About Struxicon at the "CIFE e-commerce in design and construction" summit in March, 2000: http://www.stanford.edu/group/CIFE/ecom.company.summary.html

trust (e.g., epinions.com) and sophisticated statistical analysis (openratings.com). However, we argue that none of these solutions directly addresses the problems facing an AEC electronic market, being either overly simple (ebay and Bizrate), or requiring a substantial amount of transaction data to calculate the ratings (Openratings). We therefore argue that a new approach is necessary. This paper investigates how different theoretical frameworks can be used as a basis for an AEC rating system. We propose a model for calculating ratings of AEC subcontractors based on the user's assessment of rater credibility. The paper reports the results of an experiment where the participants evaluated subcontractors using a both a credibility-weighted rating model and a standard unweighted model. The experiment showed that the credibility-weighted model fared better in terms of user behaviour as well as attitudes.

THEORETICAL FOUNDATIONS OF THE STUDY

There are several candidate methods that can be used for synthesizing uncertain information from sources of varying reliability. Zacharia et al (1999) have proposed a complex rating mechanism where the weight of the ratings depend on the user's trust in the rater along with the rater's previous rating behavior. However this rating mechanism equates trust in a business partner with trust in a rater. It is far from certain that a general contractor that is regarded as a trustworthy employer of subcontractors is also a reliable rater. Zimmerman and Zysno (1983) and others (Chen and Chiou 1999; Romaniuk and Hall 1992)) has applied fuzzy set theory to the credit rating processes conducted by banks. A process which is similar to an AEC subcontractor rating problem. Another potential solution is to deploy subjective probabilities using, for example, Howard's 5-step interview process (Howard 1984) to estimate the expected value and variance associated with a set of subcontractor ratings. A common problem with the methodologies discussed above is that they work very well once one has obtained the right input information. If one models and accurately measures the reliability of a source and how it interacts with the message (rating), the synthesizing of the information can be done in a consistent and non-arbitrary manner. However, without the correct input a synthesizing function provide little value in itself. Instead, we argue that the major problem in creating a functioning rating mechanism seems to be to accurately model and measure the reliability of the sources. Unless this can be done in a non-arbitrary manner, the algorithms serving to calculate the overall rating add little value in a real world situation. A very different way to approach this problem is to take recourse in communication research where source credibility theory has been developed to explicitly judge the credibility of media sources. In the following paragraphs we investigate how source credibility can be operationalized and extended in order to "rate the rater" in an AEC rating system.

Source Credibility theory

The foundations to source credibility theory were laid by Hovland et al (1953) who identified perceived trustworthiness and perceived expertise as the main dimensions of a source's credibility. The higher the trustworthiness and expertise a source is perceived to have, the higher will be the importance given to information coming from that source. Early work in the field applied source credibility in the context of public opinion (Berlo et al. 1969; Hovland et al. 1953; Hovland and Weiss 1951) and interpersonal communication. (Berlo et al. 1969). Later studies have shown that source credibility theory applies also applies to commercial settings where the receiver of information is evaluating possible transactions (e.g., (Birnhaum and Stegner 1979), (Fisher et al. 1979), (Harmon and Coney 1982)). We hypothesize that source credibility can also be used to assign weights to different raters in an AEC rating system. To operationalize source credibility we propose applying the validated McCroskey (1966) 12 item Likkert scale. The McCroscey scale measures a source's credibility in terms of two factors: Authorativeness (corresponding to Expertise) and Character (Trustworthiness).

However, rater credibility is not the only factor that influences the weight of a rating. .Zacharia et al (1999) point out that time is another important factor. Based on interviews we have found that ratings that were more than two years old were often regarded as substantially less credible than recent ones, even though the discount factors seemed to be highly individualized.

Stone and Stone (1984) reported that information from two sources was perceived to be more credible than information from a single source. As a result, a user evaluating subcontractors would find it useful to know the total rater credibility or the sum of the credibility of all raters that have rated a given subcontractor. Has only one rater with low credibility rated a subcontractor, or is the overall subcontractor rating based on the ratings from several very credible raters?

Feedback consistency has also been found (Stone and Stone 1985; Albright and Levy 1995) to be an important indicator when assessing the accurateness of performance feedback from multiple sources.

TRUSTBUILDER: A RATING TOOL OPERATIONALIZING SOURCE CREDIBILITY THEORY

In order to investigate in how source credibility theory can support AEC ratings the research team designed TrustBuilder, a rating tool that weighs ratings by rater credibility. TrustBuilder uses two types of information that can support the evaluation of rater credibility: direct knowledge about the rater, and knowledge about the rater's organization. This credibility weighted rating tool follow a 3-step process:

Step 1: Credibility Input – TrustBuilder lets the user rate three different types of raters on the 12 item McCroskey credibility scale[2]. The three types of raters being assessed are:

i) **Unknown Rater:** The user does neither know the rater nor the organization the rater works for. This assessment is used as a baseline measure of credibility.

ii) **Unknown rater, Known organization:** This measure is used to estimate the credibility of the organization the rater is working for.

iii) **Known Rater, Known organization:** This measure refers to raters that the user knows personally.

Step 2: Calculation of Rater Weights – The next step is to convert the ratings of rater credibility to weights. TrustBuilder does this through logistic regression in combination with a methodology of pairwise comparisons. Pairwise comparisons have been widely adopted in decision-making tools that apply the Analytic Hierarchy Process (AHP) (Saaty 1980). In TrustBuilder, the users are shown a user interface where a painting subcontractor ("PaintA") has been rated by two raters.

[2] The McCroskey scale is a 12 item semantic differential 7-point Likkert scale. The 12 items have been shown to factor into the two dimensions Authorativeness (Expertise): "Reliable", "Uninformed", "Unqualified ", "Intelligent", "Valuable", "Inexpert"; and Character (Trustworthiness): "Honest", "Unfriendly", "Pleasant", "Selfish ", "Awful", "Virtuous", "Sinful"

Figure 1: The user performs pair-wise comparison to enable TrustBuilder to calculate rater weights of ratings through pairwise comparisons and logistic regression.

Rater 1 rated PaintA's performance as "Good", while Rater 2 rated it to be "Poor". TrustBuilder asks the users to submit their assessment of PaintA's performance by dragging a continuous slide-bar in between the values "Poor" and "Good". This value (w_{12}) - corresponding to the weight that the user attributes to Rater 1's ratings vis-à-vis Rater 2's - is then used as the target function in a logistic regression to estimate the credibility (C_{ij}) of each rater j from user i's perspective. An overall rating (R_{ik}) of a subcontractor k, customized for user i can then be calculated using the following straight forward formula:

$$R_{ik} = \sum_j R_{ij} * C_{ij} / \sum_j C_{ij} \qquad (1.1)$$

$$R_{jk} \neq 0$$

Furthermore, TrustBuilder uses an adoption of a raw agreement index (see for example (Uebersax 2001)) to calculate rater agreement. The adoption consists of incorporating the notion of rater credibility when calculating rater agreement. Total credibility is simply calculated as the sum of all the raters' individual credibility.

Step 3: Display Ratings and Rater Information – In the prototype user interface the user can see the calculated values for two different subcontractors (see Figure 2.) The user can see the overall rating (weighted by credibility) both on a continuous scale and as a symbolic value. For each subcontractor, she can also see the rater agreement along with the total credibility of all the raters. TrustBuilder also shows the credibility for each rater customized by user preferences. The prototype allows the user to input contingency for each bid and select the best bidder.

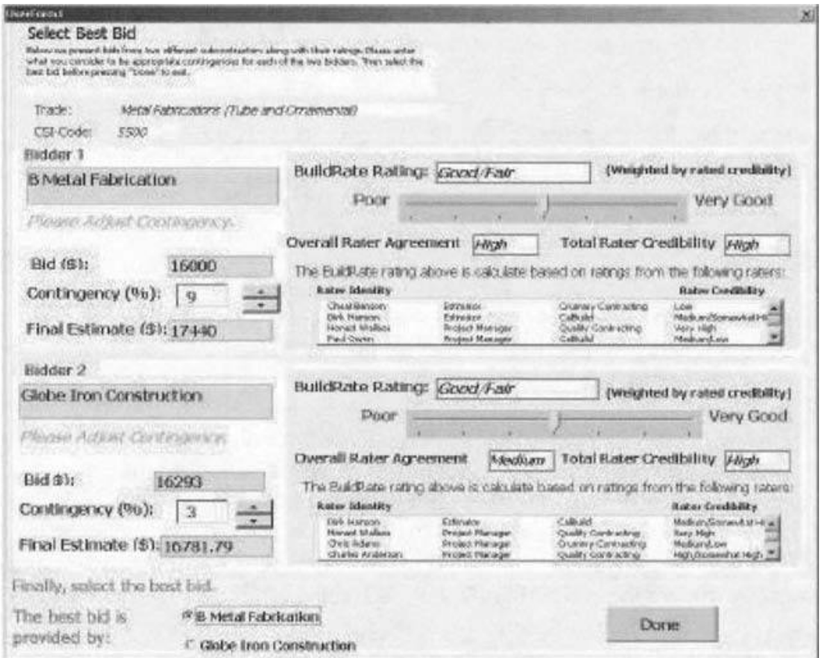

Figure 2: User interface showing bids and ratings for two subcontractors. TrustBuilder also shows rater credibility and agreement. The user inputs contingency for each bid and selects the best bid.

AN EXPERIMENT TO EVALUATE RATING SYSTEMS FOR BIDDING

In order to test the applicability of source credibility theory as a basis for an AEC rating system we designed an experiment that compared two different rating mechanisms along with the absence of ratings:

Unweighted Ratings: The subcontractor's overall ratings are calculated as the average rating where all raters are weighted the same. This is the standard mechanism similar to for example eBay's and Bizrate's systems.

Credibility-weighted Ratings: This tool corresponds to TrustBuilder, described above, where each subcontractor rating is weighted by the user-defined credibility of the rater. The rater is shown the overall rating along with total rater credibility and agreement. The major purpose of the experiment was to compare the performance of this mechanism to that of the unweighted mechanism.

No ratings: The users do not have any ratings to support the subcontractor evaluation. We included this mechanism to have a baseline measure to which we could compare the two other rating mechanisms.

The participants used the three rating mechanisms (or tools) to evaluate subcontractors bidding for the trades subcontracted in the construction of a recently completed $5M office building in San Francisco, California.

The experiment was designed to investigate the following hypotheses:

H1*: In the context of participants making pair wise comparisons, credibility measures based on the McCroskey scale are better than a unweighted (constant) model at predicting the relative weights that users attribute to different raters.*

H2*: Users will vary the contingency added to the subcontractors' bids more when using the credibility-weighted tool than when using the unweighted tool.*

H3*: The use of a credibility-weighted rather than an unweighted tool results in increased user confidence in the user's judgments of overall performance.*

H4*: The aggregated rating of a subcontractor is negatively correlated to the contingency added to the subcontractor's bid.*

H5*: The rater agreement regarding the performance of a subcontractor is negatively correlated to the contingency added to the subcontractor's bid..*

H6*: The total credibility of all the raters that have rated a subcontractor is negatively correlated to the contingency added to the subcontractor's bid.*

Method

Participants

The participants were 16 construction management students, faculty and professionals (ages ranged between 24 and 55, M= 34.5, SD=9.3). They were all familiar with AEC bidding and fluent in English even though they were of various origins (European= 8, Asia=6 and North America=2). The participants were randomly assigned to the condition regarding the order in which the different rating tools were presented.

Procedure

The experiment was a within subject design that was carried out on an individual basis with each participant being supervised by an instructor. The experiment was carried out on a personal computer at the participant's place of work. The instructor began by showing the participant a 10-minute tutorial introducing the concept of rating systems. The user then started a Microsoft Excel/Visual Basic application that ran the experiment. The participants first calculated rater weights following TrustBuilder procedure outlined above. They then evaluated one pair of subcontractor bidding for each of the project's 17 trades. For each pair of subcontractors, one of the three tools displayed bids, subcontractor ratings and rater information. The participants were asked to add contingency to each bid along with selecting the best bidder.

Manipulation

Given the exploratory nature of the study the experiment was carried out using hypothetical subcontractor ratings and bids.

The unweighted rating tool was a simplified version of the credibility weighted rating tool. The user could see the average rating on both a symbolic and continuous scale along with the number of people that had rated the subcontractor. However he did not know who had rated the subcontractor.

The tool without ratings was very simple. It consisted of the two subcontractors' names and bids.

Measures

Rater credibility was measured with the McCroskey 12 item credibility scale.

Goodness of fit of model was measured using the sum of squared errors in the pairwise comparisons for the two models.

Bid contingency was measured with a single item. The users entered a number between 0-100% for bid contingency. The contingency was intended to reflect both the user's assessment of the risk buffer that should be added to a bid, as well as the extra cost of managing an under-performing subcontractor.

Users' confidence in their assessments was measured with a single item: "How confident are you in your judgment?"

Results

Goodness of Fit

To test H1 (that a credibility-weighted model was better than an unweighted model at predicting rater weights) a generalized maximum likelihood ratio test was performed (see for example (Rice 1995)). This test compared the sum of squared errors of the unweighted and the credibility weighted models, taking into account the higher degrees of freedom of the credibility-weighted model. The sum of the errors were considerable larger for the unweighted model (17.52) than for the credibility-weighted model (5.11, $p<0.0001$) (see Figure 3.)

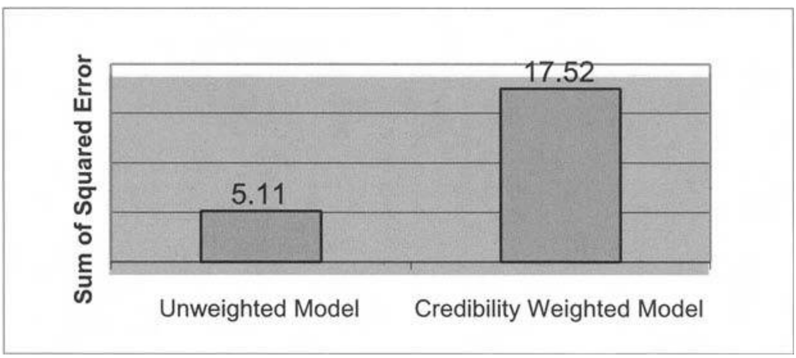

Figure 3: Sum of Squared Error in pairwise comparison using unweighted and credibility-weighted models (N=336). The results are consistent with H1 (that a credibility weighted model is better than an unweighted model at predicting rater weights).

The result indicates that the credibility-weighted model is superior to the unweighted model when it comes to predicting of rater weights (H1). One conclusion is that the TrustBuilder operationalization of source credibility theory can be used to model weights in the context of AEC bidding. This property is a prerequisite for the application of a successful rating tool.

To further test the applicability of source credibility to an AEC bidding context, we performed a principal component factor analysis. The factor analysis showed that the McCroskey scale did indeed factor into the two factors Character and Authoritativeness, indicating that measuring credibility in terms of Expertise and Trustworthiness seem to be valid also in AEC bidding.

Contingency

We used the Sign Test to test whether users varied the contingency more using the credibility-weighted tool (H2. First, we calculated the variance of the contingency assigned by each user when using each of the three tools. The form of data yielded from the survey was deemed suitable for analysis by the Sign Test following the criteria and procedures set out in Cohen and Holliday (1982). As shown in Figure 4, 14 out of 16 users varied the contingency more when using the credibility-weighted tool than when using the unweighted tool (Sign Test: n+ 14, n- 2, p<0.005.), users varied their decisions more when using a credibility-weighted tool than when using no tool. (Sign Test: n+ 15, n- 1, p<0.001).

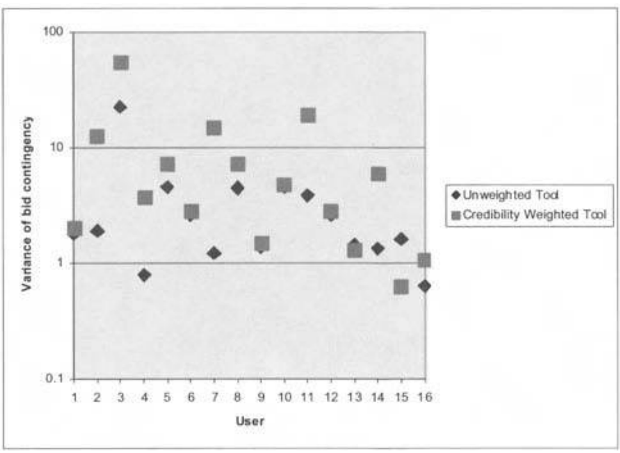

Figure 4: Variance of contingency for each user with the unweighed and credibility weighted tools. 14 out of 16 users had a higher variance when using the credibility weighted tool.

The results indicate that the users will vary their evaluations of subcontractors more using a credibility-weighted tool. As a result, the bidding price will be of less importance. A user would then be less likely to select the lowest bidder when using the credibility-weighted tool than when using the unweighted tool. This is an important finding since the purpose of a decision support tool such as a rating system is to provide the user with information that she trusts enough to act upon.

Confidence

The participants expressed higher confidence in their evaluatons (H2) when using the credibility weighted tool (M=5.97, SD=2.00) than in the unweighted tool (M=5.00, SD=3.83, N=16, paired t-test: $p<0.005$.). Similarly, the confidence was higher when using the credibility-weighted tool than when using no tool (M=3.15, SD=2.19, N=16, paired t-test: $p<0.005$). The results for the attitudinal confidence measure were consistent with the results for the behavioural measure of bid contingency. A confident user will be more likely to vary his decision depending on the information provided by the rating tool.

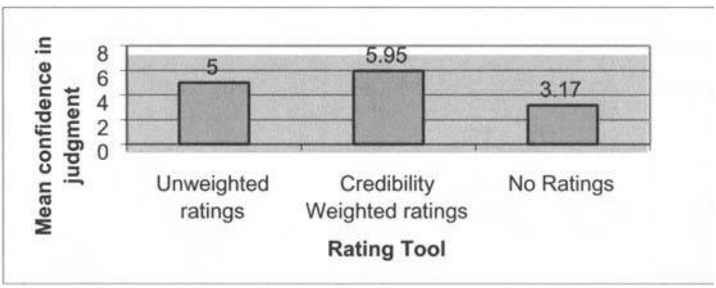

Figure 4: Confidence in judgment using three different rating tools. Users expressed more confidence when using the Credibility weighted tool.

Agreement and Total Credibility

The study also intended to investigate to what extent Average Rating Agreement and Total Credibility influenced bidding decisions (H4-H6). For the tested set of raters, both agreement ($p<0.01$), total credibility ($p<0.05$), and Final (Aggregated) Rating ($p<0.01$)) were shown to influence bid contingency (Figure 5.) The coefficients are all negative since the better the overall rating, the higher agreement of the raters, and the more trustworthy these raters are perceived to be, the lesser amount of bid contingency a user will feel inclined to add.

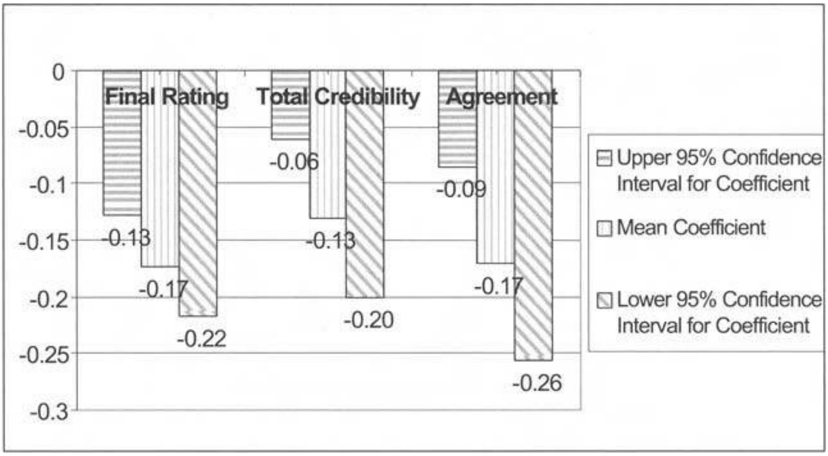

Figure 5: Coefficients in Linear Regression of Bid Contingency using credibility-weighted tool. The results show that the users base their bid contingency decisions not only on the Final Rating, but also on Agreement and Total Credibility.

DISCUSSION

The study suggests that source credibility is a promising basis for an AEC rating system. The experiment found differences between a credibility-weighted and an unweighted model both in terms of a behavioral measure (contingency) and an attitudinal measure (confidence). The results indicate that, by knowing that the ratings are filtered by rater credibility, users become more confident in their decisions, and hence more likely to let the rating tool influence their decisions. That the users trust the ratings is a key aspect for a successful deployment of a rating system in an AEC electronic marketplace. General Contractors that trust the sucontractor ratings provided by a rating system would be less reluctant to hire a subcontractor they had not hired before.

Furthermore the study indicates that especially rater agreement but also total rater credibility affect user's evaluations of subcontractors. If further aggregation is strived for, a rating tool could calculate a final overall rating incorporating the overall credibility weighted rating, the level of agreement, as well as total rater credibility. For a tool that is designed to support human decision-making this level of aggregation may not be called for. However, a credibility-weighted rating mechanism could also support the automaton of low risk labor-intensive tasks. One example would be an automated bid invitation tool that invites all the subcontractors who fulfil a set of criteria covering (e.g., minimum overall rating, minimum safety record, maximum bond rate, etc) to bid on a job

In future research we plan to repeat the experiment in more realistic conditions, having industry practioners, that are experts in evaluating subcontractor, apply different tools to evaluate a real set of subcontractors. The TrustBuilder rating tool can also be elaborated by refining the 3-step process calculating credibility weights and by extending it to include more than one rated criteria.

Finally, we want to emphasise that a rating system that accounts for rater credibility will not be able to enforce truthful behaviour in an Internet rating system. A prerequisite for a functioning rating system is that a substantial fraction of the participants in the system behave altruistically by supplying honest evaluations. Still, we predict that a credibility-weighted tool would provide the user with a means to filter out ratings of dubious nature. The use of a credibility-weighted tool is also advantageous for the subcontractors who are rated in the system. Some of them may object to being rated out of fear of receiving "unjust" ratings from ill intending general contractors. If the system weighs the ratings by rater credibility the subcontractors can feel certain that the effects of any dishonest ratings will be limited. A general contractor who provide inaccurate ratings are less likely to be perceived as credible, and as a result their ratings will have less impact on the overall ratings. As a result, a credibility-weighted rated tool could be an important building block in a framework to create trust in AEC e-commerce. By rating the rater the user of AEC e-market places can come one step closer to trusting new business partners.

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Theme 3: Innovative Project Delivery Systems

Improving contractor/subcontractor relationships through innovative contracting.

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ABSTRACT

Various forms of relationship contracting have being adopted by many industries to improve business or project outcomes. Although partnering and, to a lesser extent, alliancing are currently being used within the construction industry to improve the management of client - main contractor relationship, they are not being applied to main contractor - subcontractor relationship to the same magnitude. Despite the increasing extent of subcontracting in the industry, with as much as 90% of all construction work being undertaken by subcontractors, the importance of subcontractor relations is frequently underestimated.

This paper outlines a preliminary study on the implementation potential for relationship contracting between main contractors and subcontractors in the construction industry. The work reviewed current systems, surveyed contractor and subcontractor perceptions and investigated ways project outcomes could be enhanced. The surveys and case studies undertaken highlighted the limitations posed by the lump sum contractual arrangements which are typically used. The research found that strengthened relationships, more effective problem resolution and more equitable risk allocation could all greatly enhance project outcomes in terms of cost and time savings and increased construction innovation. Although informal or quasi - partnering relationships do sometimes form, both contractors and subcontractors felt that further benefits could be achieved from implementation of relationship contracting in a more formalised manner. A number of barriers were however identified and the research concludes that detailed trials need to be undertaken and standard procedures established before relationship contracting can be successfully executed on a wide scale within the industry.

Keywords: relationship contracting, partnering, subcontractors, construction management.

INTRODUCTION

The need for the construction industry to be innovative and improve its efficiency through improved management has been the subject of much research over the last fifty years. From the Simon Report in 1944 (CCWB) to the Latham Report in 1994 (Latham, 1994) the separation of the design and construction processes, selection of contractors on the sole criterion of price and the subsequent lack of cooperation between those involved in the development process have been cited as being at the very core of the industry's problems.

Although much work has been conducted to reduce the impact of these issues, which manifest in time and cost overruns, increased litigation and an inability to meet client requirements they still trouble the industry and limit its success (Godfrey, 1995; Mulvey, 1998). Globalisation, too, has lifted the standards and levels of sophistication expected by construction clients (Thompson & Sanders, 1998; Masterman, 1992) and construction companies need to improve the way they work to meet those demands.Japan appears to be to a model for this trend. Bennett and Jayes (1998) claim it has achieved the most efficient construction industry in the world based on long term client relationships, job security and commitment to improvement. This efficiency leads to better project outcomes including jobs that finish on time, to budget and with near zero defects.

Relationship contracting uses a number of ideas from Japanese systems (Green, 1999). It developed through the quality movement of the 1980's as a way of improving relationships between clients and providers in a number of industries (Baden-Hellard, 1996). It has been implemented within the construction industry to assist in the management of the client/main contractor relationship and endeavours to reduce conflict, align client–contractor objectives and develop better risk sharing mechanisms promoting win-win outcomes between those involved.

However the delivery capability of a construction firm is determined to a large extent by the quality of its subcontractors. The work undertaken by specialist and trade contractors within a project has increased significantly and can now account for as much as 90% of the total value of the project (Nobbs, 1993; Kumaraswamy & Matthews, 2000). This suggests subcontractors play a vital role within the project, a role that should be carefully managed to ensure optimal outcomes. Use of contracting methods where price is the sole criteria for selection leave it open to the same problems as those experienced in traditional contracts between client and contractor.

This paper outlines a preliminary study investigating the implementation potential of relationship contracting between contractors and subcontractors in the Australian construction industry. It reviews contractor and subcontractor perceptions and ways project outcomes could be improved. The research was limited to the non-residential building sector in Australia, which is one that relies heavily on subcontractors.

WHAT IS RELATIONSHIP CONTRACTING?

Relationship contracting is a broad term encompassing a number of specific strategies such as partnering, project alliances and strategic alliances. It aims to prevent disputes, foster cooperation and facilitate completion by improving the relationship between stakeholders through a mutually developed strategy involving commitment, communication and teamwork (Baden-Hellard, 1996).

While the principles have been around for centuries they have only recently been developed as a formal strategy in which to establish working relationships amongst stakeholders (Green, 1999). It can be used with or as an alternative to more traditional methods of building procurement and all forms use delivery strategies based on a closer alignment of client and contractor objectives and better risk sharing mechanisms promoting win-win outcomes. Some approaches also provide for decision-making structures and alternative methods of dispute resolution (ACA, 1999). Walker *et al* (2000) note that the key difference between the three forms is the contractual status of the relationship which impacts on how the relationship evolves and their associated benefits.

The partnering continuum model (Thompson & Sanders, 1998) in Figure 1 below illustrates how increased benefits can be gained as relationships move away from competition to coalescence. Traditional forms of tendering involve individual goals being pursued. However in collaborative and coalescence relationships, such as alliances, strategic goals for all parties are sought with project goals intrinsically linked to the individual objectives of all participants. Partnering falls in to the stage of cooperation whereby the parties endeavour to align individual goals so that by working towards mutual goals those of individual parties are achieved. A key way to achieve alignment of goals is through sharing of risk associated with the contract (ACA, 1999). By developing mutual goals and risk in respect to target cost or completion it becomes in both parties interest to reduce rather than increase costs (Baden-Hellard, 1996).

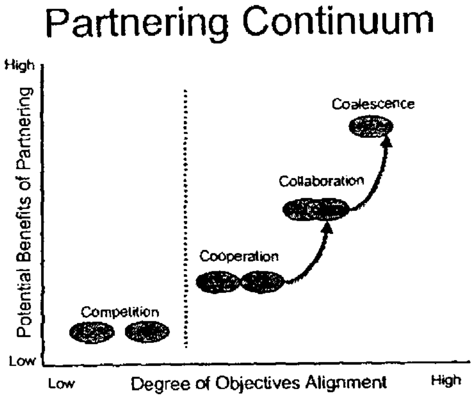

Figure 1 Partnering Continuum model

Relationship contracting has been in use in Australia since the early 1990's and was identified as an important component of the Building and Construction Industry reform agenda, formulated by the Federal Government in 1991. Uher (1999) estimates that hundreds of partnered projects have been undertaken in Australia over the last decade and a number of studies, both industry and project based, have been undertaken looking at their success (Li & Green, 1996). Project and Strategic alliances have been used to a much lesser extent with only one known alliance project in the non-residential building sector (Walker et al, 2000). Their use is more common in engineering construction and manufacturing works (Thompson, 1998). However little attention has been given to the role of subcontractors within this structure (Uher, 1999).

The role of subcontractors

Hinze and Tracy (1994) define subcontractors as speciality contractors hired to perform specific tasks on a project. These companies fall into three main categories: trade contractors, specialist contractors and labour-only, with trade contractors generally undertaking the majority of subcontracted work. Uher (1999) found that the majority Australian building projects use the subcontracting system and it is now common for them to undertake 80-90% (Hinze & Tracy, 1994) of work on a project. This is a significant increase and has effectively shifted the business emphasis of construction companies to being the managers and instigators of the construction process rather than direct labour employers.

The majority of subcontracts are awarded through some form of competitive bidding (Hinze & Tracy, 1994) which has been shown to create potential for conflict, particularly in the event that the most advantageous outcome for one party and optimum project outcomes are mutually exclusive (Mohsini & Davidson, 1992). A number of systems have developed to ensure tenders meet minimum performance requirements such as use of 'registered subcontractors' or pre-qualification (Karamuswamy & Matthews, 2000. Tenders are normally awarded on a lowest price basis. Unfortunately this can lead to bid shopping with many contractors perceiving their greatest cost saving potential lies with subcontractors. Unfair contract conditions are common where obligations, as stipulated in the contract between the client and main contractor, are passed onto subcontractors who do not get the opportunity to view it. Ease of entry into the subcontracting market and a decline in training (AEGIS, 1999) results in many subcontractors not having the expertise to provide the service required. Payment problems too add to the conflict potential: however this issue is being addressed through the introduction of security of payment legislation. The increasing size and importance of the subcontractor's role within the industry amplifies the value and importance of effective management of the contractor/subcontractor relationship.

A survey of the Australian construction industry found that subcontractors consistently work for the same contractors (Gyles, 1992). Thirty six percent only undertook projects for one client/ contractor, with a further thirty four percent working for no more than three major contractors. This suggests that the contractor/subcontractor relationship is not a one-off or project specific relationship as was argued in Hinze and Tracey (1994) and improvements could have long term benefits. Latham (1994) supports the idea that informal alliances currently exist in the industry with his observation that some main contractors have developed long-term relationships with subcontractors. Hampson and Kwok (1997) clarify this by introducing the term working relationship. They found that the formal or working relationship is typically on a project-by-project basis but they did not eliminate the option of less formalised long-term relationships. The duration of this relationship is a key difference to client-contractor relationship where projects are generally undertaken for different clients on a one-off basis (Godfrey, 1995), This indicates that the potential to benefit from relationship contracting may be greater in contractor-subcontractor relationships.

Relationship contracting with subcontractors

Although there is a large body of work addressing use of relationship contracting in client-contractor relationships application to subcontracts seems to have been largely over looked. Matthews (1999) has carried out the most substantial work in this area to date when he investigated a methodology for implementing contractor/subcontractor partnering. He outlined a semi-project partnering approach, involving limited competition, adopted by a UK company. The approach used the principles of partnering but the term "semi" was used in recognition that true partnering is based on negotiation. The technique involved the project team nominating 3 to 5 subcontractors for each work package and selection based on abilities, response to partnering, innovation and indicative price.

Successful subcontractors were then involved in a one day partnering workshop which developed a partnering charter and issue resolution policy with follow up one day meetings every 3 months. Matthews notes that although tendering costs were increased it has been found to be very worthwhile. There is no evidence of such a formalised system existing in Australia. Matthews also summarised the relative benefits of partnering from published literature and categorised them for each of the main stakeholders. The three most cited benefits he identified for subcontractors are noted below:

- Improved decision-making avoids costly claims and saves time and money.
- Reduced exposure to litigation through communication and issues resolution strategies.
- Increased opportunity for a financially successful project because of non-adversarial win-win attitude.

Kumaraswamy and Matthews (2000), in a survey of contractors and subcontractors, found that project outcomes could be improved through positive attitudes, compliance to commitments, correct and quick responses, increased trust and fair dealing with subcontractors and earlier involvement of subcontractors. These all support improved relationships between the parties.

RESEARCH OBJECTIVES AND METHODOLOGY

The research involved the preliminary investigation of the implementation potential for relationship contracting between contractors and subcontractors. In particular the research set out to answer four specific questions or objectives.

- How successful are current delivery systems in managing the contractor/subcontractor relationship?
- How could outcomes be improved by use of relationship contracting?
- What barriers prevent the successful use of relationship contracting?
- What is the potential for implementation?

The data was collected from project managers and subcontractor representatives involved in recently completed projects using a self-administered questionnaire.

Questions were developed from issues identified in a literature review. In particular current outcomes and the perceived effect of factors that can affect project performance was assessed using criteria in Table 1. These criteria were adapted from those used by Love, 1997 and Love, Skitmore & Earl, 1998.

Table 1 Ideal Contractor and Subcontractor Performance Criteria

The Ideal Contractor	The Ideal Subcontractor
Accepts responsibility for own work. Time – Reasonable schedules, continuity of work, coordination of trades. Price – Fair prices for variations, payment on time. Demands a reasonable level of quality in design, materials, and workmanship. Flexibility to changes in design and site conditions. Makes decisions/resolves conflict promptly. Safety performance. Cooperation - easy to work with, considered projects best interest Minimal claims and disputes Communication	Accepts responsibility for own work Time – adherence to schedules Price – completion on or below budget Quality of design, materials, workmanship Flexibility to changes in design and site conditions Ability to handle complex, highly specialised work Safety performance Cooperation – easy to work with, considered projects best interest Minimal claims and disputes Communication

Survey sample

The study was undertaken with the support of an Australian owned construction firm undertaking projects throughout Australia in the non-residential sector for both public and private clients. The company normally subcontracts close to 95% of its work. Focussing on one contractor reduced the effect of variables and produced responses with an immediate audience and application. As all subcontractors undertake work for a variety of contractors their responses do however provide insight into general industry feeling.

Projects were selected that had been recently completed or were nearing completion. These provided a cross-section of different project values, procurement methods, and building types normally undertaken by the construction firm. None of the projects used relationship contracting between the contractor and subcontractor.

This was typical of all projects undertaken by the company. Project managers were selected to complete the contractor questionnaires. They were identified as most qualified to judge the effect of actions, attitudes and relationships on the success of the project most aware of project performance factors such as time, cost, disputes etc. Cross checks with other staff within the organisation was beyond the scope of this preliminary study.

Subcontractor supervisors were selected to complete the subcontractor questionnaires as they were considered to have the best understanding of both site and company issues. Five key trades were identified namely concreting, plastering, painting, electrical and plumbing. Selection of these trades was based on a number of factors:

- Occurrence on all projects surveyed and representative of the industry.
- Relatively large involvement and contract value – increasing the value of any benefit.
- Varying coordination needs and technical complexity.
- Involvement in different phases of the project.

The subcontractor sample size was significantly reduced as multiple responses from the same subcontractor working on more than one of the projects (60% of the sample) was considered unworkable due to the confusion it would cause. This high percentage does however indicate that informal relationships must exist.

RESEARCH FINDINGS

Contractor and subcontractor questionnaires focussed on identifying opinions of how successful currently used delivery systems are in managing contractor/subcontractor relationships, whether relationship contracting could improve project outcomes and what barriers and support there was for implementation.

Eleven questionnaires by project managers and fifteen completed representing a return rate of 92% and 38% respectively. Two thirds of the projects surveyed had contract values of A$10 to 20 million. Traditional delivery methods between the client and main contractor were used on the majority of projects however one project used design and construct. Another project used value management as part of its procurement strategy and some subcontractors were involved in this process. On all projects subcontractors undertook between 95 and 100% of construction work. The subcontractor companies surveyed take on 10 to 30 projects per year for 4 to 10 contractors and 50% had been operating for 25-40 years. All subcontractors used were listed in a company subcontractor performance register as they had been previously used on other projects. Although this produces some degree of pre-qualification it is not a company requirement for letting of subcontracts.

How successful are current delivery systems in managing the contractor/subcontractor relationship?

Lump sum tender was the most common method for obtaining subcontractors, it was used on 72% of projects and negotiated lump sum was used on 55% – some projects used more than one method for different subcontracts where it was deemed best for the circumstances. The most common reason (64%) for selection of these methods was alignment with the head contract, enabling transfer of risk. This suggests the client/main contractor delivery method had a significant effect on subcontractors.

The success of current relationships, dispute resolution procedures, risk allocation and performance on the projects in question were rated on a five point likert scale with (1 = poor, 2 = fair, 3 = average, 4 = good and 5=excellent). They provided some interesting results.

Although lump sum tenders were used for the majority of contracts their success in building positive relationships between the contractor and subcontractor was rated as average to poor on all but one project. Use of negotiated lump sum was seen to be slightly more successful but most effective on projects that had a successful client/main contractor relationship. Subcontractors were more positive about the success of relationships than contractors although many noted that relationships deteriorated over the course of the project, suggesting they could benefit from better management. This more optimistic response could also be due to an induced bias from respondents not wanting to be perceived as being critical of their appointing body.

The results of the contractor and subcontractor responses to dispute resolution are summarised in Table 2. Lump sum contracts also contributed to ineffective dispute resolution with poor response times, lack of innovative and practical solutions and win-win outcomes for both parties. The two projects using design and construct and value management did not experience these problems to the same extent, suggesting that improved client/contractor relationship had a large effect on contractor/subcontractor relationships.

The results suggest neither party feel they are getting fair outcomes but again subcontractors were slightly more satisfied. This is supported by the results from the questions on risk allocation, with 82% of contractors rating the incentive to cooperate and fairness of risk allocation as poor to average. However this was still a higher figure than that obtained from subcontractors. Overall the results in Table 3 on risk allocation highlight an area that has significant potential for improvement.

Respondents were asked to rate current performance if improvements were achieved in three areas normally improved through relationship contracting. These areas were relationships between parties involved, dispute resolution and risk allocation.

Current performance was assessed using the same 5-point likert scale (with 1 = poor and 5 = excellent). Again the projects involving design construct and value management both performed better. The percentage of respondents who felt the performance against the specified criteria was to a good to excellent standard is noted in the second column of tables 4 and 5 below.

The contractors rated subcontractor's current performance poorly overall with excellent (5) never recorded against any of the criteria. Subcontractors were generally more positive about contractor current performance, however overall results were still average rather than excellent suggesting significant potential for improvement. In particular subcontractors felt they were not fairly treated with regard to time and price demands nor were contractors accepting responsibility for their own work.

Table 2 Effectiveness of Contractor/Subcontractor Dispute Resolution Procedures with Respect to Criteria

Performance criteria	**% of respondents who rated procedures as being poor to average**	
	Contractor	*Subcontractor*
Response time	82	60
Innovative/practical solutions	82	60
Win-win solutions	64	70
Decision making	82	70

Table 3 Effectiveness of Risk Allocation Within the Contract With Respect to Criteria

Performance criteria	**% of respondents who rated effectiveness of risk allocation as being poor to average**	
	Contractor	*Subcontractor*
Fairness to both parties	82	70
Incentive to co-operate	82	70
Risk allocated to parties who control them	64	80

How could outcomes be improved by use of relationship contracting?

Respondents were asked to rate the likely effect on their counterpart's performance as worse, same or improved for the same performance factors and criteria. The percentage of respondents who felt the criteria could be improved is noted in Tables 4 and 5.

Interestingly while contractors and subcontractors anticipated showed similar overall figures for improvements the two parties highlighted quite different priorities. Contractors identified improved relationships as having the strongest effect on project outcomes while subcontractors identified more equitable risk allocation as being the most important factor. Both parties also placed different weighting on these performance factors. Overall contractors were generally positive about the benefits of relationship contracting processes, with only two responses stating it will have a negative outcome. They felt it would have a positive effect on cost and time with little effect on quality, safety and ability to undertake complex work. Subcontractor results anticipated general improvements in all criteria.

Table 4 Contractor Survey Results

Performance criteria* (listed in ranked order of importance)	**% subcontractors** who perform criteria to a good to excellent standard	**% of contractors who felt criteria could be improved by:**		
		Improved cont/ subcont relations	*Improved problem/ dispute resolution*	*More equitable risk allocation*
Cost	18	55	18	45
Time	18	82	45	82
Safety	27	9	9	9
Quality	18	45	18	18
Responsibility own work	18	72	45	73
Minimal claims & disputes	27	64	82	73
Co-operation	9	73	64	82
Communication	27	73	82	73
Ability for complex work	0	36	18	9
Flexibility	9	100	36	45
Average overall support		60	42	51

Table 5 Subcontractor Survey Results

Performance criteria* (Listed in random order)	**% contractors** who perform criteria to a good to excellent standard	**% of subcontractors who felt criteria could be improved by:**		
		Improved cont/ subcont relations	*Improved problem/ dispute resolution*	*More equitable Risk allocation*
Accepts responsibility own work	27	53	60	53
Time - reasonable schedule, continuity	27	53	73	73
Fair price & payment on time	27	38	53	66
Demand reasonable level quality	53	60	67	60
Flexibility to changes	40	47	73	60
Decisions & conflict	47	53	47	53

attended promptly				
Safety performance	47	40	60	53
Co-operation	47	53	53	60
Minimal claims & disputes	40	40	46	60
Communication	47	60	60	60
Average overall support		50	59	60

What barriers prevent the successful use of relationship contracting?

Contractors felt the barriers with the greatest potential to affect implementation of relationship contracting were legal implications (100%) and lack of experience (90%). These two areas must be looked at carefully when reviewing potential for implementation. They also felt that the cost to implement would be a key factor preventing its use.

The barriers most commonly identified by subcontractors were lack of experience (93%), compromise to contractual status (80%). Cost to implement was also a factor for both parties. Subcontractors were less worried about the legal implications than contractors. As noted previously the client/contractor contractual relationship was found to have a significant effect on contractor/subcontractor relationships. The benefits of relationship contracting would be limited if adversarial contractual arrangements were used in the head contract.

Subcontractor's exposure to the industry suggests that if the industry continues to operate in an adversarial manner this will have an effect on all projects undertaken by that contractor; pressure placed on one project will affect ability to perform on others therefore limiting performance on projects using Relationship Contracting.

What is the potential for implementation?

The contractors and subcontractors surveyed felt that relationship contracting could improve project outcomes and were interested in undertaking projects using these methods. Some project managers had experience of partnering. While they supported future use of relationship contracting contractors identified a number of considerations that should be made prior to use. There was a general feeling that processes should be trialled on one project prior to widespread implementation, similarly project alliances should be mastered prior to participating in long-term strategic alliances. They felt it was important all parameters are agreed prior to implementation to ensure all parties contribute 100%. They felt that relationship contracting could provide significant advantages but pressures for competitive tenders will always limit its success.

All but one subcontractor was interested in using relationship contracting. Subcontractors suggested most support for strategic alliances, possibly to secure long-term work. They also expressed support for use of partnering and project alliances.

Table 6 Barriers That Prevent Implementation of Relationship Contracting

Potential barriers	% of respondents who rated effectiveness of risk allocation as being poor to average	
	Contractor	*Subcontractor*
Cost to implement	80	60
Lack of experience with process	90	93
Compromised by contractual status	50	80
Individual risk minimisation	50	27
Previous experience	50	27
Legal issues	100	73

Table 7 Contractor and Subcontractor Willingness to Undertake Projects Using Various Forms of RC

Forms of relationship contracting	% of respondents who would like to undertake projects involving relationship contracting	
	Contractor	*Subcontractor*
Partnering	73	87
Project Alliance	91	93
Strategic Alliance	73	87

CONCLUSIONS

This preliminary research showed that potential does exist to implement relationship contracting between contractor and subcontractors in the Australian construction industry. Both parties are generally unhappy with current project outcomes (particularly in regard to cost and time performance; which were identified as the most important factors to contractors) and see relationship contracting as a method to provide better but different outcomes.

Previous work has shown that partnering and alliances between clients and contractors have been successful and it could be surmised that its prospects in the contractor–subcontractor relationship must be even greater due to the longer nature of these affiliations. However, both parties' wariness of formalising these relationships suggests more standardised procedures need to be developed and the potential success tested prior to its adoption by industry. Key barriers limiting usage were identified as:

- the implications of the contract between client and contractor.
- lack of experience with relationship contracting.
- the legal implications of relationship contracting.
- the cost of implementation.

Relationship contracting will be most effective where client–contractor relationships operate on similar principles – if these are adversarial and inflexible this will have flow on effects to the contractor–subcontractor relationship and will limit its potential. The lack of experience in relationship contracting could be over come by innovative contractors trialling it on projects and developing standard procedures for implementation. Matthew's (1999) semi-partnering approach may be a good starting point. Transparency in the process and documentation of results quantifying savings will assist in acceptance on projects requiring stricter probity rules and enhance industry-wide commitment.

Development of different standard forms of contracts for the different forms of relationship contracting could reduce costs, assist in increasing familiarity with methods and ensure the rights of all parties are protected. Similarly analysis and dissemination of information on the legal implications of implementation should be undertaken. As subcontractors and contractors become more familiar with the methods implementation cost will reduce.

The decision of which method should be used is a difficult one. Each method will provide different benefits and suit different projects types and contractor/subcontractor objectives. This research found that subcontractors saw strategic alliances ultimately as providing the best potential for them as it provided a significant level of security. Contractors perceived this securityand lack of price competition could have a negative effect on projects and were more positive about using project alliances before entering into to a longer-term agreement. Partnering could be used as a stepping-stone and should not be disregarded. As the industry is notoriously slow to change, an incremental approach may be prudent to help build up trust and long term commitment.

RECOMMENDATIONS FOR FURTHER RESEARCH

The contractor–subcontractor relationship is one that merits further study and more needs to be done to promote subcontractor involvement in this area of research. This paper was preliminary in nature and further work on larger samples needs to be conducted before further research and education is undertaken to develop implementation processes. Further research should be undertaken into the legal implications of using relationship contracting for contractor–subcontractor relationships and standard forms of contracts developed for each form of relationship contracting. Many aspects of the relationship particularly evaluation of the key needs of both parties should be examined with in-depth studies to identify how best to optimise project outcomes.

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Resistance to Best Value Procurement in the Construction Industry

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ABSTRACT

The procurement delivery system of choice in the construction industry has been the competitive low-bid award. The process includes detailed specifications and drawings (design, construction means and methods, and legal terms of the contract). As economies have moved into the information age and influenced by the price pressures of the worldwide competitive marketplace, contractors have been forced to become more competitive by finding ways to lower their price. This process has affected the quality and capability of the construction industry. The construction industry has been quick to blame non-performing construction (construction that is not on time, on budget, meeting quality expectations of the owner) on the designers' and the owners' low-bid award process. However, when given an opportunity to change to a value added, information based performance procurement process, the construction industry has been slow to embrace the change. This paper gives a theoretical explanation for the current construction industry position, and supports it with results from the State of Utah and the State of Hawaii. The results identify the construction industry's resistance in moving to an information age and detail the management of such resistance.

INTRODUCTION

The construction industry has experienced low profit margins in a high-risk industry, reduction of trained craftspeople, and performance and dispute issues (Angelo, 2001, Post, 2001, Kashiwagi, 2001, Gibson, 2001). The specification, low-bid delivery system has been identified as a possible source of the problems. However the uniqueness and complexity of construction projects, the lack of performance information and information technology, and the hierarchical nature of the industry has made it difficult to identify the extent of the impact of the design-bid-build process on construction performance.

The worldwide competitive marketplace has forced owners to become price sensitive. The facility and design managers representing the owners do not have performance information to minimize risk (minimization of risk: construction on-time, on-budget, or meeting their quality expectation). Therefore, in many cases, owner representatives have been forced to select the low bidder. This has transformed the designer's role from producing documents showing design intent to producing a regulatory document, which includes design requirements, minimum standards, and means and methods. This environment becomes devoid of performance information (data that differentiates contractor's ability to minimize risk). It has allowed poor performance, an industry to survive with inadequate training, and contractors minimizing their risk by transferring it back to the owners. Owners are attempting to minimize their construction risk by moving to other delivery systems including design-build, construction management @ risk, and Indefinite Delivery, Indefinite Quantity (IDIQ) contracting. The authors propose that alternative delivery systems will not succeed unless an information environment is implemented and performance (using performance information) and price are utilized in procurement.

Theoretical Discussion of the Relationships of Level of Information to Other Factors

Information is defined as data and theories that differentiate and accurately describe the conditions of reality in terms of relative differential, minimize uncertainty, and predict the future outcome (Kashiwagi, 2001). If an individual or organization perceives a high level of information, they will perform similar to a Type 'A' (on-time, on-budget, and meet quality expectations) and by definition, continuously improve (change) at a relatively high rate (Figure 1).

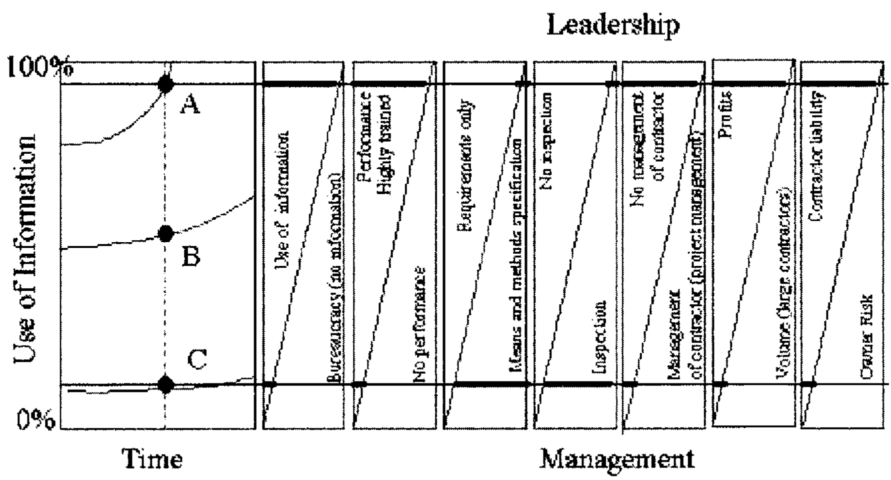

Figure 1 Rate of Change and KSM Information Levels

However, if their use of information is relatively low, they will change at a very low rate, have many rules and by definition be bureaucratic and not pass information (Type C in Figure 1). Accepting the assumption that construction is unique for each project, and that representative samples of data for analysis would be very difficult if not impossible to obtain to differentiate in the midlevel area (Type B area), only the extreme areas will be analyzed. Figure 1 also includes two-way Kashiwagi Solution Models (KSM) that shows the two opposite elements similar to the 'ying and yang' principle. The objective of the two-way KSM charts is to identify if a criteria is on the top hand side, or the bottom hand side. By definition, the Information KSM is on the left hand side. As the level of information is increased in the Rate of Change chart, the KSM shows an increase in information and a decrease in the amount of activity of not using information. The chart shows that if you do not have all information, by definition, you will have times when there is no information. The KSM deductively assumes that all factors across the KSMs are relative and related (Hawking, Kosko, Zeleny.) The actual slope of the dividing lines becomes irrelevant at the extremes. The research will verify the KSM extremes by deduction and identification of the conditions by the current construction environment.

The 'Amount of Information' KSM is shown first. In other words, if the user differentiates among contractors by using their performance information, they have a higher position on the KSM and the Rate of Change chart. This will result in having a contractor with higher performance. Therefore performance is done by those who have high levels of information or expertise and is a left side characteristic. Performing contractors perform because they have personnel who are highly experienced or trained. Performance based contractors need requirements instead of means and methods. Therefore a means and methods specification is a right side characteristic. The more detailed means and methods specifications are required, the less trained and performance based the contractor needs to be. This is not making the conclusion that highly trained contractors cannot use means and methods specifications. It is stating that highly trained and performing contractors have little need for means and methods specifications, and have a more difficult time competing based on first price with contractors who may be inexperienced and need directions.

Owner inspection adds the most value when contractors are not quality oriented. A quality-oriented contractor will find flaws that an inspector will miss, unless the inspector was once a high quality contractor. Inspection is therefore a right side characteristic (inspection decreases as contractor skill increases). Contractor profit is a left side characteristic. The contractors with high quality craftsperson skill requirement will make a higher profit because they are minimizing risk, re-work, and lifecycle cost, and giving higher quality. This includes the specialty contractors who often make a higher profit than the general contractors. Conversely, contractors who leverage volume to get work, often reduce their price to get more work. Therefore, leveraging volume is a right side characteristic. Training is a left side characteristic. Training is required more for specialty work than for commodity construction or laborer work. Inspection by the owner is a right side characteristic. When high quality specialty work is required, and the contractor is highly skilled, it is difficult to add value by inspecting the contractor. However, if the contractor is not a high quality, the contractor must be highly inspected and directed.

The high performing contractor is also more likely to take upon themselves the risk of nonperformance due to their ability to minimize risk. However the more poorly trained contractors would not be willing to take upon themselves the risk of nonperformance. In low-bid procurements, with very low levels of performance information being used, and the owner representatives attempting to direct and control the construction, the contractors have a low level of risk and liability. The high information environment includes the following characteristics:

1. Minimized risk due to the high performance contractor.
2. Transfer of the minimized risk to the contractor.
3. Training.
4. Minimized means and methods specifications and inspection.
5. Higher profit and lower volume.
6. Lower control and direction of contractor by owner's representative.

The current construction industry (Post, 2001) matches the environment in Figure 2 of minimum performance and high competition. It is not in the interest of all construction delivery participants to bring change to status quo environment and move it to Quadrant II (performance based or best value). The following groups may not have motivation to bring about the information environment.

Designers may fear an information environment due to the perception that their job is to write regulatory specifications, control, inspect, and manage construction (right side, Figure 1 and Quadrant I in Figure 2). These functions are minimized in the information environment (left hand side, Figure 1 and Quadrant II in Figure 2). Designers must be re-educated return to their core competency of design, and to fit comfortably in an information environment.

Performance information would not be advantageous for large contractors currently leveraging volume. Large contractors are currently viewed as successful. They leverage volume for price (do more work for less profit). In an industry with a lack of craftspeople and construction managers, they are trying to do more work for less money (Figure 2).

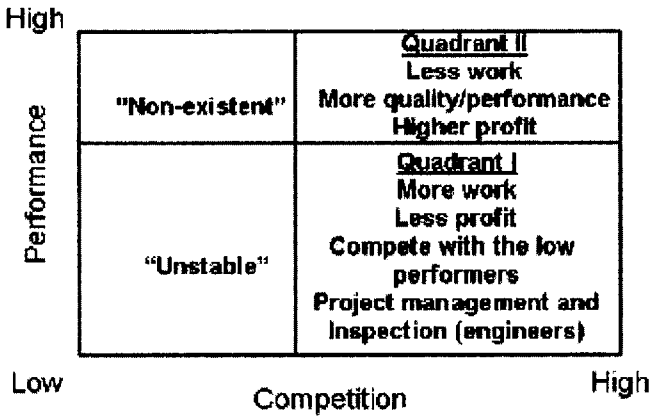

Figure 2 Construction Industry Structure

Facility management would also be affected by performance information. The current low bid system brings the risk to the owner. The owner's representatives are directing the contractors and inspecting the work. However, in an environment with very little information, the owners may not know they have high risk (Figure 1, right side). If they had the performance and risk information, they may restructure, use a more efficient process, and minimize their construction management staff. This fear motivates many facility management personnel to maintain the status quo where nonperformance is blamed on the contractors instead of their inefficient system. An information environment also minimizes the need for construction litigation.

It may not be in the best interest of all construction industry participants to move to an information environment. However, the worldwide pressure to be competitive, to lower expenditures, and to reduce staff will push the information environment upon the construction industry.

The Performance Information Procurement System (PIPS) was developed in 1991 at Arizona State University. It is a procurement process that uses contractors' past performance information and current capability to minimize risk of nonperformance. PIPS allows facility owners to procure construction based on performance and price (Kashiwagi, 1999, Kashiwagi and Mayo, 2001). PIPS uses a pre-qualification stage where past performance information is collected. Contractors then bid on a construction project. They are requested to submit a management plan which consists of the identification of risk of the project to the owner (not finishing on-time, within budget, and meeting quality expectations), how they will minimize the risk, a general construction schedule, how they would value engineer the project if it was their facility based on their construction expertise, and a detailed cost breakout. An artificial intelligent processor (modified Displaced Ideal Model (DIM) (Zeleny, 1985)) is then used to prioritize the contractors in terms of best available performer (past performance, current capability to minimize risk, and performance of critical elements of the team.) PIPS then considers performance and price in a final prioritization of options. The PIPS process forces the top prioritized contractor to go through a self risk evaluation as well as a technical review. The contractor agrees to take the intent of the design and construct it as proposed in their management plans, interview, and clarifications in the preaward phase. Figure 3 shows the information filters that make up the PIPS process.

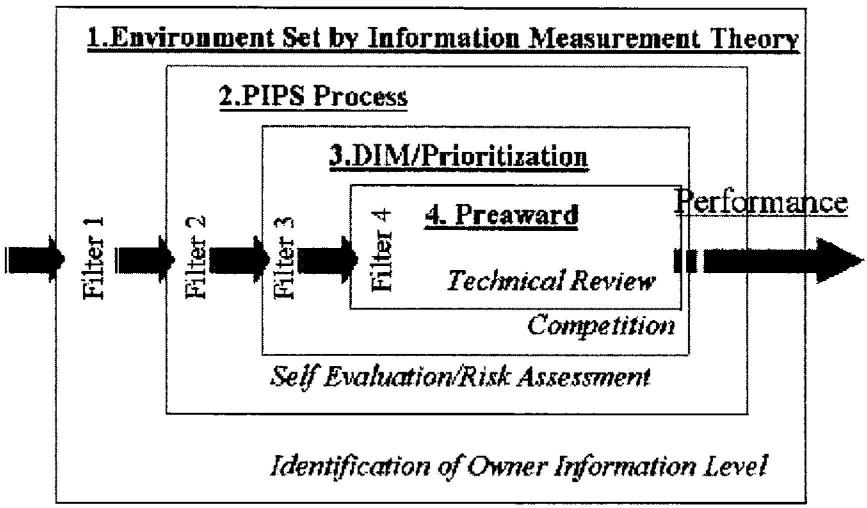

Figure 3 PIPS Process by Information Filters

PIPS uses business practices and information principles identified by Deming (1982) (information, no minimum standards, no inspection), Drucker (1993) (use all possible information, make decisions when information is not required), Buckingham and Coffman (1999)(work with performers, disassociate from nonperformers, use information), Gates (use interface of human and computer technology, use all possible information, social adaptation of technology is obstacle), McKinsey (2001) (minimize work, use the right information structure, minimize risk), and Welch (Trout, 1986) (simplify complex situations, assign responsibility, understand performance) to minimize the risk of nonperformance. PIPS minimizes directives on means and methods, allows contractors to identify their capability to minimize risk, and minimizes control over the contractor while holding them responsible to perform. PIPS has the following track record (Kashiwagi, 2001):

Over 300 tests on \$160M of construction procurement, \$50M - \$10K projects.

General and specialty construction, design-build, new, and retrofit construction.

Private sector and government sector.

Users include the states of Wyoming, Utah, Georgia, and Hawaii, Federal Aviation Administration (FAA), United Airlines, Honeywell, and IBM.

A record of 99% of jobs on time, on budget, with no contractor generated cost change orders.

Reduction of construction management by 80%.

The difference in performance as rated by the owners in comparison with the low-bid system is 20% more effective.

PIPS can be described using the left hand side or information environment (Figure 1). It verifies that when using performance information, the other characteristics of the left hand side also exist. Each owner is unique and has a different level of performance. The States of Hawaii and Utah both ran PIPS. The State of Hawaii started their implementation in 1998. They had originally planned for a five year development starting with simple roofing and painting projects and moving on to more complex general construction projects. A great deal ~~lot~~ of effort was spent training a core team made up of personnel at the executive, management, and project levels. The State of Hawaii has now run 150 projects with 99% being on-time, on-budget, and meeting the expectations of the users. As the successful results were documented, the State of Hawaii expanded the PIPS implementation to more projects due to an unusually heavy construction requirement. As the PIPS expanded, pockets of resistance began to appear.

As predicted in the theoretical discussion above, resistance came from industry participants who were not used to the concepts of an information environment (minimized owner control, specifications, directions, and high contractor skill, performance, transfer of risk to the contractor, and documentation of performance information). Resistance came from general contractors who were used to leveraging price, and specialty contractors who had a difficult time understanding performance. Government personnel, due to their lack of understanding of performance concepts, resisted by requiring unnecessary documentation and control mechanisms that were not required and would not take the lead in certain PIPS steps, slowing down the implementation. The majority of designers participating in the PIPS projects had difficulty estimating project costs and over-designed their projects. There reaction to their error was to question PIPS for raising the cost of the projects. This was not substantiated by the contractors' bids and other low-bid projects. Despite the high performance results (average 9.5 out of a possible 10.0), the resistance against the new process showed the difficulty in bringing change to the construction industry.

The State of Utah tested PIPS on 6 construction projects, totaling $80M. Unlike the State of Hawaii, the State of Utah was attempting to eliminate a low-bidding problem and nonperformance construction that threatened the timely completion of the 2002 Olympic Village Housing at the University of Utah. Three contractors were awarded the six projects. While the projects were being awarded some of the larger, better-known contractors insinuated that the project awards could not be based on performance, since they were not awarded any of the projects. However, the greatest resistance came from designers because the Facilities Group at the State of Utah decided to run PIPS on the designers as well as the contractors (Utah Building Board Meeting, August 2000). PBSRG advised the State of Utah not to proceed with using PIPS on the designers since it was unsuccessful in the State of Hawaii.

All the construction projects finished on-time (within the control of the contractor not including scope changes and delays caused by incomplete design or delays from other projects), on-budget, and met quality expectations. The Director of the State of Utah described the construction as the "Best construction the State of Utah had received in the last 10 years" (Byfield letter, 2001). However, the State of Utah ran into resistance in continuing the PIPS process. Unlike the State of Hawaii, they had not trained a core team. They had no trained personnel and no funding to do any training. General contractors who had not been awarded projects were complaining that the system was unfair. The Director of Facilities turned the problem over to an advisory building board to solve the problem.

One of the problems of resistance to a new concept is to change the concept before the test results are completed. The board formed a task force, which modified PIPS to become more subjective (use less information). Some of ideas of the board members and industry personnel who wanted the process modified were not congruent with the information theory or the PIPS test results. The head of a procurement task force, who did not have any performance information from the PIPS projects nor received any PIPS education, stated that the "...formula and barcode frightened many of the participants in the Task Force..." and recommended that it not be used (Utah Building Board Meeting, July 2000).

The State of Utah moved to a subjective process where a group would see all the information and then subjectively choose the winning bid. The general contractors also convinced the advisory board that performance ratings on the critical subcontractors was unimportant, even though later, one of the observations on the completed PIPS projects was the importance of performing critical subcontractors. The State of Utah modified PIPS and called the process Value Based procurement. They reduced the number of references from 40 to 10, the number verified from all to 3-5, eliminated performance ratings of subcontractors, and used a subjective award process instead of the PIPS artificial intelligent system. The process will work better than the low-bid system, but increases subjectivity and decision making which will move it back to the low-bid level of low information (Figure 1).

The author recognized that contractors who were not awarded projects took the approach that because they were not selected, they were not high performers. They did not realize that performance is dictated by the owner and is unique to a particular project. Another impact of the PIPS implementation was the fear of some contractors and designers would lose a substantial part of their work. A major shift the contractors experienced in moving from low-bid to PIPS bidding was the uncertainty caused by the lowest bidder not necessarily getting the award. Understanding the value of the PIPS award took more effort by both the contractors and the user's representatives. The designer's were also faced with the possibility of having their miscalculation of construction cost identified by everyone in the information environment. In the previous environment, a low bidder would usually bid with in the budget and process change orders after the fact. In the PIPS environment, the risk is transferred to the contractor, and there are no contractor generated cost change orders, unlike the low-bid environment where the error is camouflaged by a low bidder making an estimating error. The information environment clearly identifies those at risk and errors before the award.

Managing The Resistance To the Information and Performance Environment

Based on the two test cases, the authors conclude that implementing PIPS will bring resistance from general contractors, designers, government personnel who are not used to using or passing information, and any other party which does not monitor their own performance with goals and information. To implement an information based process will require the following strategy. Resistance to the process should be managed in the following way to minimize resistance:

1. Prototype test the process with a small core team.

2. Do not force anyone to participate.

3. Plan to use it as another procurement delivery method for high risk projects and not to replace the low-bid system (non-informational.)

4. The implementation should be slow. It should start with simple projects and move to more complex projects over a period of three to four years.

5. Have a continuous education program for designers, contractors, and government personnel who are involved in the process.

6. Identify and publish bid and construction performance information as soon as possible.

7. Do not make a decision on the process before the results of the test is completed.

8. When PIPS is run by personnel other than the core team, documentation has to be in place for them to implement the process.

These actions will assist in managing the resistance to the information environment. The resistance will be further minimized by the resulting higher profits, pride in performing work, and the owner's willingness to allow the performing contractor to do their job.

CONCLUSIONS

The information age will force the construction industry to increase performance through the use of performance information. The increase in information will lead to higher performance, higher profits for performing contractors, higher trained craftspeople, and different roles of facilitation for designers, engineers, consultants, and inspectors, and less project management of the contractors. The concept has been proven in a large number of tests. The key element is the use of new technologies, a nonbiased performance information generator (artificial intelligent model that makes decisions based on relative differences) and the contractors being rebarcoded by their performance on projects. However, there will be resistance to the change. The current industry has functions and practices which have been proven to be inefficient and non-value added in other industries (means and methods specifications and inspection). Personnel involved with these functions and practices will resist change. The resistance can be managed and minimized by using PIPS and the information environment as an alternate delivery system, implementing slowly, educating participants, and publishing the performance results. The construction industry is hierarchical, slow changing, does not adapt to technology well, and fears the unknown. If the change is not managed properly, the resistance will be too great to implement an information environment.

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Use of Design-Build-Operate Contracts for Infrastructure Projects

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ABSTRACT

The traditional procurement strategy for most infrastructure projects in the United States historically has been design-bid-build. The Seattle Public Utilities department has selected a design-build-operate procurement strategy for the construction and operation of two major water filtration facilities. This alternative strategy was selected because the city lacked experience in plant design, construction, and operation and desired to minimize its life-cycle costs for the projects. This paper describes the procedures used by the city and the results obtained. Construction of the first plant has been completed, and it is now in operation. The second plant is currently under construction. The city estimates that it saved about 40% in life-cycle costs for the first plant and about 30% on the second one.

INTRODUCTION

Historically, the traditional procurement strategy for most infrastructure projects in the United States has been design-bid-build. The Seattle Public Utilities (SPU) Department has selected a design-build-operate (DBO) procurement strategy for two major water filtration and ozonation facilities. The alternative strategy was selected because the city lacked experience in plant design, construction, and operation, and the DBO approach might offer cost savings when compared with the design-bid-build project delivery method. The city has completed the construction of one treatment plant on the Tolt River and has started the second on the Cedar River.

This paper describes the procedures used in the selection of the contractor for each project, the results obtained, and some lessons learned. Risks and responsibilities were consolidated, giving the contract participants a stake in the performance of the completed facility. The DBO procurement strategy resulted in considerable cost savings for the Public Utilities Department.

DBO APPROACH

The DBO procurement process differs substantially from typical public works contracting, where construction contractors are asked to bid on a detailed design, and the lowest responsive bidder is selected. In contrast, the DBO procurement process starts with the creation of performance specifications that describe desired project outcomes. Proposers are asked to develop their own designs to achieve those outcomes. The selected contractor manages the design and construction of the project, assuming the risk for project implementation. When construction of the project is completed, the contractor assumes responsibility for operating the facility, training staff, and guaranteeing operational performance for a specified period of time. The procurement process used by Seattle consisted of five major steps.

Define the Project

This step involved selecting the general project philosophy, the procurement strategy, a work plan, and a preliminary schedule. The project management team identified key project issues, selected an approach to establishing facility and performance specifications, and developed a preliminary risk allocation matrix. A communications protocol was established identifying a single contact person for all questions, prohibiting contact with elected officials, and requiring that all questions be submitted in writing. To disseminate project information, a project Website was created.

Solicit Contractor Qualifications and Develop Short List

A request for qualifications (RFQ) was issued that outlined the owner's facility design and construction objectives and plant operations and maintenance objectives. The RFQ requested statements of qualifications (SOQ) from interested proposers. The statements of qualification were evaluated using a predetermined set of criteria, and the highest ranked firms were selected for the short list of contractors that would be invited to submit detailed proposals. The Washington State statute governing DBO procurement requires that three to five firms be selected for the short list.

Issue the Request for Proposals

A request for proposals (RFP) was issued to the firms on the short list. It described performance specifications and plant minimum requirements and provided proposers with a list of documents that must be submitted with their proposals. The RFP also indicated that unsuccessful proposers would receive honorariums ($100,000 for Tolt River and $150,000 for Cedar River). A draft service agreement was issued to each proposer with the RFP. Prospective proposers were given three months to develop their proposals, and a preproposal conference was conducted to address proposer questions.

Evaluate Proposals and Select Contractor

The RFP specified the criteria that Seattle would use in evaluating the proposals. The criteria included team, technical, and economic factors. The evaluation committee conducted a multi-step process to understand and evaluate the proposals. This process involved individually evaluating the proposals, obtaining input from technical consultants, and discussing as a group the relative merits of each proposal. In addition, the evaluation committee conducted telephone interviews to determine the performance of each proposer's management team on other projects, conducted site visits to other projects operated by each proposer, and conducted personal interviews with each proposer's proposed management team. Once the evaluations were completed, Seattle issued clarifications and requested best and final offers from each proposer. Based on the final offers, a contractor was selected.

Negotiate the Contract

Negotiations were conducted in three phases. In the first, the city identified its major issues and concerns, which were resolved through collaborative work sessions. The second involved exploration of facility enhancements, and the third involved finalization of the service agreement terms and conditions.

RISK ALLOCATION

One of the major objectives of the city when it selected the DBO delivery method for the plants was to allocate the project risks in a manner that minimized overall project costs. This meant assigning the risks to the party (owner or contractor) best able to manage them. A comparison of the procurement strategies considered by Seattle is shown in Table 1. The city wanted an integrated team approach to design, construction, and operation and wished to transfer the risk relating to these activities to the contractor, but was willing to assume the cost of financing risk. It wanted to retain ownership of the plant and to take advantage of tax-exempt financing to reduce capital costs. Seattle also wanted to award the contract based on life-cycle (design, construction, and operation as well as maintenance and equipment renewal and replacement) cost, not just design and construction cost.

Table 1 Comparison of Alternative Procurement Strategies

	Project Characteristics		
Procurement Strategy	Level of Integration	Operational Responsibility	Ownership and Financing
design-bid-build	fragmented	owner	owner
design-build	partial	owner	owner
design-build-operate	complete	contractor	varies
build-operate-transfer	complete	contractor	contractor

To transfer the permitting, design, and construction risk, the city decided to award these phases of the project to the contractor on a lump-sum basis. A retainage of 5% would be withheld from all contractor payments until acceptance testing of the facility is completed (SPU, 2000). The contract provides for a 25-year operating period (15-year base period and two 5-year options). The contractor is paid a service fee for plant operation. The service fee has two components: a fixed component for operation and maintenance (including replacement of all components costing less than $10,000) and a variable component for insurance, chemicals, and energy which are treated as reimbursable costs without mark-up. Replacement of components costing over $10,000 are to be financed by the city. Seattle required a single, financially strong guarantor for all phases of the project. The primary reason for requiring a guarantor was that the city did not want to find itself in the center of any disputes among members of the DBO consortium.

The resulting risk allocation for both projects is shown in Table 2.

Table 2 Risk Allocation

Risks Assumed by City	Risks Assumed by Contractor
financing	permitting
site acquisition	design
raw water quality	construction
changes in legal requirements	operation
	treated water quality

QUALIFICATION CRITERIA

The RFQ invited respondents to submit SOQ describing their technical, management, and financial qualifications to permit, design, construct, and operate the facility. It contained detailed descriptions of the project site and discussed major environmental considerations. Respondents were given 45 days from the issuance of the RFQ to submit their SOQ. A pre-SOQ submission conference and site tour was conducted by the city two weeks after the RFQ was issued.

The SOQ (SPU, 1999) was required to include the following information as a minimum:

- General company/team information including project organization chart
- Technical qualifications, including DBO experience, design experience, sustainable design and construction experience, regulatory compliance and permitting experience, construction experience, and operation experience
- Relevant project experience
- Financial statements
- Project guarantor

The SOQ were evaluated and ranked using a 100-point evaluation system. Sixty points were allowed for team and technical qualifications, and forty were allowed for financial qualifications (SPU, 1999). The top ranked respondents were placed on the short list and issued the RFP. Ten firms submitted SOQ for the Tolt River project, and four were selected for the short list. Five firms submitted SOQ for the Cedar River project, and three were selected for the short list.

RFP REQUIREMENTS

The RFP (SPU, 2000) contained submission instructions, outlined the evaluation criteria, and provided proposal forms (schedules) that were to be completed and included in the submission. Because the city desired to promote creativity and cost competitiveness in the procurement process, it encouraged innovation by allowing proposers flexibility with respect to the selection and configuration of treatment processes. The following project information was provided:

- Description of project site
- Capacity requirements
- Design criteria, including allowable technologies
- Operational requirements
- Permitting requirements

Respondents were given four months in which to complete and submit their proposals. A pre-proposal conference was conducted two weeks after issuance of the RFP. The following proposal format was specified by the city:

- Executive Summary
- Technical Proposal
- Business/Financial Requirements
- Proposal Forms
- Experience and Qualification Information

The RFP stated that the annual service fee would be adjusted each year based on an operational price index to account for inflation. It also indicated that monthly bonuses would be paid for superior performance and that liquidated damages would be assessed for supplying treated water that did not meet regulatory requirements.

The technical proposal was to include a description of the treatment facility and its related components including proposed systems and approaches to water treatment. It also was to include conceptual drawings showing the hydraulic profile, architectural elevations, power and electrical systems, structural design, instrumentation and communication approach, process controls, repair and replacement plans, and provision for emergency operations.

The business/financial information required included the project guarantor commitment, a fixed price for obtaining all necessary permits, designing the plant, and constructing it as well as an anticipated payment schedule and a service fee for the 15-year base period and each of the 5-year options. It also was to contain estimated reimbursable costs for chemicals, energy, and insurance and anticipated major maintenance, repair, and replacement costs. The final documents required in this section were the performance and payment bonds.

EVALUATION CRITERIA

The following evaluation criteria were specified in the RFP (SPU, 2000):

- Financial criteria
    - Proposal price
    - Financial qualifications

- Team/technical criteria
    - Proposer experience/technical qualifications
    - Project implementability
    - Project sustainability
    - Technical feasibility and reliability
    - Environmental protection and mitigation

The financial criteria were evaluated with a maximum value of forty points, and the team/technical criteria with a maximum value of sixty points. The cost-effectiveness of each proposal was determined by using a present worth life-cycle cost analysis considering the fixed design and construction cost, the operation and maintenance service fee, estimated major maintenance and replacement costs, and estimated reimbursable costs for chemicals, energy, and insurance.

A consortium made up of Camp Dresser & McKee and Azurix Corporation working with Dillingham Construction was selected as the contractor for the Tolt River plant, and CH2M Hill working with Mortenson was selected as the contractor for the Cedar River plant. Unsuccessful proposers on the Tolt River project were paid $100,000 honorariums, while those on the Cedar River project were paid $150,000 honorariums. Discussions with the contractors indicate that these honorariums covered about 10% of the costs they incurred in preparing their proposals.

RESULTS ACHIEVED

Seattle was extremely pleased with the results of the DBO procurement strategy for the two water treatment plants. The Public Utilities Department was able to transfer the risk of design, construction, and operation and achieve significant cost savings as indicated in Table 3 (Kelly, 2001). The city estimates that it saved about 40% on the Tolt River plant and about 30% on the Cedar River plant.

Table 3 Project Costs

	Tolt River	Cedar River
Design-bid-build estimate		
Capital cost	$115 million	$115 million
Operational cost (25 years)	$56 million	$49 million
Total cost	$171 million	$164 million
DBO contract		
Capital cost	$65 million	$81 million
Operational cost (25 years)	$36 million	$32 million
Total cost	$101 million	$113 million

LESSONS LEARNED

Seattle learned several major lessons as a consequence of its DBO experience. It is essential that the owner develop a project approach early in the process and that it have a clear understanding of project performance requirements. Project risks should be allocated to the party best able to manage them. A draft contract should be included in the RFP to aid prospective proposers in evaluating their risks. To be successful, the owner needs to understand the market for such projects and prospective proposers. During implementation, project owners need to understand corporate relationships and constraints and to maintain open and positive lines of communication. Owners also must resist the temptation to direct the design and manage the project.

CONCLUSIONS

A DBO procurement strategy has much to offer on many infrastructure projects. It allows selection of a contractor and project scope based on life-cycle costs and places single responsibility for design, construction, and operation on one party, the contractor. This results in an integrated approach to project delivery that considers the trade-off between capital costs and operational costs. Selection of low-cost components often results in higher operation cost, either for maintenance and repair or for energy consumption. DBO procurement takes time, almost two years for each of Seattle's projects, but offers the potential for innovation and cost savings. Use of a single project guarantor provides the owner protection against any disputes among members of the contractor consortium.

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Financing Strategies for Build-Operate-Transfer Projects

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ABSTRACT

The build-operate-transfer (BOT) delivery method has been used for many infrastructure projects in various countries. In this delivery method, the project sponsor is responsible for financing, designing, and constructing the project and operating it for a certain concession period. Project sponsors face several major risks when executing these projects. Financial success depends on an analysis of the risks to be faced and the selection of an appropriate mix of equity and debt financing. This paper contains an analysis of alternative project financing strategies and examines several transportation and power-generation BOT projects. The findings indicate that political, financial, and market risks had the greatest influence on the selection of appropriate financing strategies.

INTRODUCTION

The build-operate-transfer (BOT) delivery method has been used extensively for infrastructure projects in various countries. Under the BOT approach, the project sponsor is responsible for financing, designing, and constructing the project and operating it for a certain concession period. During the concession period, the project sponsor collects revenues from operating the project to repay the project costs as well as to provide a profit. At the end of the concession period, ownership of the completed project is transferred to the host government.

Project sponsors face several major risks when executing BOT projects. These include construction risks, operation risks, political risks, financial risks, and market risks. Financial success depends on an analysis of the risks to be faced, an analysis of the possible sources of financing, and the selection of an appropriate mix of equity and debt financing. This paper contains an analysis of alternative project financing strategies and examines several transportation and power-generation BOT projects.

BOT DELIVERY METHOD

In the BOT delivery method, the project sponsor finances, designs, and builds the project and then operates it for a specified concession period. At the end of the concession period, ownership of the project is transferred to the granting authority. Two well-known projects that were constructed in this manner are the Suez Canal, which had a 99-year concession period, and the Channel Tunnel, which has a 50-year concession period. The project sponsor collects revenues during the concession period to recover its investment and earn a profit.

Project participants include the granting authority, which typically is a government agency; the project sponsor; and one or more financial institutions. The project sponsor generally is a consortium or joint venture of engineering, construction, and venture capital firms. At the end of the concession period, all operating rights and operational responsibilities revert to the granting authority. The selection of an appropriate financing strategy depends on the risks to be faced in the project. Prospective lenders tend to focus on project risks, while investors tend to focus on opportunities for profit. Thus, the selection of an appropriate mix of equity and debt financing is important.

RISK ANALYSIS

The major risks a project sponsor faces are political, financial, construction, operational, and market risks. Political risk comes from the potential occurrence of war, coups, expropriation of assets, or government action that could influence the profitability of the project. Financial risk relates to fluctuation in currency exchange rates, inflation, and interest rates. Construction risk relates to construction delays and cost overruns. Construction delays often result in both increases in construction costs and delays in revenue collection. Operation risk relates to the cost of operating the completed facility. Market risk has two major components: a demand risk and a price risk. The demand risk is the uncertainty regarding the demand for the service or product, and the price risk is uncertainty regarding the price that can reasonably be charged for the service or product. BOT project sponsors need to understand the risks to be faced and select appropriate risk mitigation strategies to minimize their financing cost to ensure their tenders are competitive. The selection of an appropriate financing strategy is an essential component of a risk mitigation plan.

ALTERNATIVE FINANCING STRATEGIES

Debt financing for a BOT project generally is not based on the credit rating of the project sponsor or the value of the sponsor's assets. It is based on the anticipated financial performance of the project. Lenders view the anticipated revenues as the source of repayment and the project's assets as collateral. Because of the length of concession periods, BOT project loans tend to have longer maturities and higher interest rates than do traditional business loans.

The capital structure of most BOT projects is highly leveraged. Equity financing typically covers only ten to thirty percent of total project costs, while debt financing is obtained for the remaining seventy to ninety percent (Levy, 1996). A common strategy is to use as much debt as the anticipated project revenues can justify to provide an attractive rate of return to equity investors. Equity investors may be those who are solely interested in return on their investments and/or others who have a direct interest in the project. Granting authorities and lenders usually are concerned about the amount of equity provided by project sponsors. A significant level of equity investment usually is a competitive advantage when tendering a BOT project, because it demonstrates a high level of commitment by the prospective project sponsor.

BOT projects can be viewed as two distinct projects: a high-risk construction project followed by a low-risk operation and maintenance project. In some cases, long-term financing cannot be obtained at favorable interest rates until construction is completed. In such instances, project sponsors may use equity financing to finance the construction and then refinance with debt financing once the major construction has been completed.

CASE STUDIES

Six case studies (four transportation and two power plant projects) were studied in an attempt to understand the criteria used in selecting the financing strategy for a BOT project. Information regarding project characteristics, financing structure, risks and mitigation methods used, and financial performance were collected and analyzed. The following is a brief description of each project.

North-South Highway, Malaysia

The North-South Highway runs about 900 kilometers from Singapore to the Thai border, linking major industrialized areas of the country. The project sponsor is Projek Lebuhraya Utara Selatan, a wholly owned subsidiary of United Engineers Malaysia, which is a joint venture comprised of Mitsui, Taylor Woodrow International, Dragage et Travaux, and three Malaysian companies. The project sponsor provided US$775 million in equity financing and US$2.3 billion in debt financing (Fisher and Babbar, 1996). Subcontractors were paid 87 percent of their subcontract values in cash and 13 percent in equity shares. This reduced the sponsor's cash flow requirements and provided an incentive for subcontractors to perform well. Debt financing consisted of US$870 million in loans from foreign banks, US$807 million in loans from local banks, and US$634 million in government loans. The major political risks were a lack of concession legislation and the need to obtain government approval for all toll increases. The financial risk was high because large portions of the debt had floating interest rates. The estimated project cost of US$1.28 billion escalated to US$3.2 billion due to construction difficulties and exchange rate fluctuation (Walker and Smith, 1995). The contract was signed in 1988, and construction was completed in 1996.

State Route 125 South Tollway, United States

State Route 125 is a 17.7-kilometer four-lane toll road in Southern California connecting the Mexican border with State Route 54. The state government is constructing the 2.4-kilometer northern section of the highway, while a private consortium, California Transportation Ventures, Inc., is responsible for the 15.3-kilometer southern section. The consortium is composed of Parson Brinckerhoff, Egis Projects, Kock Materials, Prubache, and Flour. It will transfer ownership as well as tort liability to the state upon completion of construction and lease both sections for the 35-year concession period (Levy, 1996). The contract was signed in 1991, and construction is to be completed in 2004. Consortium participants provided $122 million of equity financing and obtained $97 million in loans and $37 million standby line of credit from the United States Department of Transportation under the Transportation Infrastructure Finance and Innovation Act (Reinhardt, 2000). Approximately $240 million in toll revenue bonds are to be sold to provide the remainder of the financing required. The project sponsor will be allowed to set toll rates, but the maximum return on capital is capped at 18.5 percent. The project has been delayed by various government and environmental complications.

Highway 407 Express Toll Route, Canada

Highway 407 runs east and west across the greater Toronto area. It is the world's first all-electronic toll road and runs parallel to Highway 401, one of the busiest highways in Canada. Completed in 1997, the Province of Ontario owned and operated the first 69-kilometer section until 1999, at which time the concession for the toll road was awarded to a private company. The contract provides a 99-year concession period and obligates the sponsor to complete a 24-kilometer western extension and a 15-kilometer eastern extension. The project sponsor, 407 International, is a consortium of Canadian and Spanish engineering and construction firms and a Canadian pension funds manager. The consortium paid US$2 billion for the completed section of highway. It is scheduled to complete construction of the additional 39 kilometers of highway in 2002. The consortium participants provided US$1 billion in equity financing, which was a combination of cash and subordinated debt. Canadian banks provided floating-rate bridge loans totalling US$1.6 billion in debt financing (Dafoe and Connell, 1999). The bridge loans are to be refinanced and an additional US$200 million of debt obtained by the sale of bonds. The only market risks the project sponsors face are the long-term traffic growth rate and the future of the local economy.

Western Harbour Crossing, Hong Kong

The Western Harbour Crossing was the third tunnel built between Hong Kong and Kowloon. The contract that was awarded to Western Harbour Tunnel Company Limited in 1992 provides a 30-year concession period. The project sponsor provided US$315 million in equity financing and US$670 million in debt financing, which included US$410 million in floating rate bank loans and US$260 million in revolving credit (Lang, 1998). The project sponsor is allowed to increase the tolls each year based an agreed range of net revenue (Levy, 1996). The major political risk on the project was the handover of Hong Kong from Britain to China in 1997. The major market risk is competition from the other two harbor tunnels. Construction was completed in 1997 and opened to traffic three months ahead of schedule. Project costs were about US$965 million.

Shajiao B Power Station, China

Shajiao B Power Station is a 700-megawatt coal-fired plant located near Tai Ping in Guangdong, China. The project sponsor is a joint venture of Shenzeun Special Economic Zone Power Development Company and Hopewell Power (China) Limited (Walker and Smith, 1995). The contract was awarded in 1984, and construction was completed in 1987. Hopewell was responsible for financing all construction costs, while Shenzeun was responsible for government interface. Hopewell provided US$128 million in equity financing and obtained US$384 million in debt financing from a syndicate of 46 international banks. A major debt package was a fixed-rate loan denominated in Japanese yen backed by the Export-Import Bank of Japan. The Chinese government provided guarantees regarding protection against exchange rate fluctuation. Revenues were structured such that fifty percent are paid in local Chinese currency and fifty percent are paid in foreign currencies converted from the local currency at predetermined exchange rates. Guangzhou International Trust and Investment Company provided guarantees on the power purchase agreement and coal supply agreement (Lang, 1998). The local currency is used to purchase coal, and the foreign currency is used to service and retire debt. The guarantees helped Hopewell acquire debt financing. The project was completed eight months early allowing the project sponsor to earn extra income and bonuses.

Paiton I Power Plant, Indonesia

The Paiton I Power Plant is a 1,230-megawatt coal-fired power plant located in East Java, Indonesia. The contract was awarded in 1994 to the project sponsor, PT Paiton Energy Company, which is owned primarily by a consortium of international companies. The sponsoring consortium provided US$680 million in equity financing and US$300 million in contingent equity. Fixed-rated debt financing of US$1.6 billion was provided by the Export-Import Bank of Japan, the Export-Import Bank of the United States, and the Overseas Private Investment Corporation, and US$180 million of debt financing was obtained from commercial banks (Lang, 1998). Perusahaan Listrik Negara Persero, the state-owned electric power authority, is to purchase all electricity generated under the power purchase agreement and must approve all tariff rate adjustments. The tariff contains two components, a variable energy payment, which is based on the actual amount of energy used, and a fixed capacity payment. Both are dominated in the Indonesian Rupiah. The economic downturn and political changes in Indonesia after 1998 caused severe problems when the project sponsor failed to make contractual payments (Cahill et al., 2001). The devaluation of the local currency also adversely affected the sponsor's ability to service the project's foreign debt. The contract is being renegotiated.

ANALYSIS OF CASE STUDIES

Risk Analysis

Analysis of the risks project sponsors faced in the six case studies indicated that construction and operation risks were more manageable than other types of risk. Most of the project sponsors mitigated the construction and operation risks by contracting out the responsibilities and using advanced, well-proven technology. The major considerations in the selection of a financing strategy, therefore, were political, financial, and market risk. These three risks were analyzed in each case study to understand how they influenced the financing strategies that were used. These risks were subjectively rated on a scale of 1 to 5, with 1 being low risk and 5 being high risk. The results are shown in Table 1.

Projects in the United States and Canada have low political risk because they have good legislative frameworks, detailed contracts, and strong government support. The political risk faced by sponsors of the Western Harbour Crossing project was related to the turn over of Hong Kong to China. Projects in Southeast Asia and China have high political risks because of the lack of concession legislation, contractual details, and government guarantees.

Table 1 Risk Evaluations for Case Studies

Project	Political Risk	Financial Risk	Market Risk
North-South Highway	5	4	3
State Route 125 South Tollway	2	1	3
Highway 407 Express Toll Route	1	1	2
Western Harbour Crossing	3	2	4
Shajiao B Power Station	4	3	2
Paiton I Power Plant	5	4	2

The financial risk depends on the host country's financial condition, the contract provisions, and the availability of financing sources. Projects in the United States and Canada have low financial risk because of the financial stability of the host countries and the availability of financing. The high financial risk scores for projects in Southeast Asia are mainly due to the condition of the host country's economies. The moderate risk score for the Shajiao B Power Station is because of the exchange rate guarantee provided by the Chinese government. Contractual language regarding revenue collection is also a major factor in determining a project's financial risk. State Route 125 South Tollway, Highway 407 Express Toll Route, and Western Harbour Crossing are projects that allowed sponsors to increase tolls without seeking government approval. Both of the power projects and the North-South Highway required government approval for any rate increase.

The market risk faced by the project sponsors was judged based on market demand, competition, purchase agreements, contractual provisions, and government guarantees. Power plant projects tend to have lower market risk, since their purchase agreements typically have a fixed fee paid by the granting authority as well as a rate for the sale of energy. Transportation projects have higher risk since they may not achieve anticipated traffic volumes. The Western Harbour Crossing project has high market risk because there are two other crossing sites.

Financing Strategies for Low-Risk Projects

Analysis of the low-risk projects (State Route 125 South and Highway 407) indicates that there are many similarities with respect to financing. Both projects were highly leveraged, had a low level of standby credit facilities, used capital markets, and had no public equity. With a low risk of cost increases, a low level of project contingency and standby credit is necessary. This results in lower financing cost. Sponsors of low-risk project often can obtain bond financing, which usually results in lower financing costs. Bond financing was used for both State Route 125 South and Highway 407. Another important criterion for bond financing is the availability of capital markets, which are still undeveloped in many nations.

Financing Strategies for High Political Risk

Political risks found in the case studies were complicated approval processes, government instability, delays, changed policies, and lack of clear legislation. Financing strategies used to mitigate the political risks were seeking assistance from influential individuals or organizations, involving international firms or organizations, and seeking government participation. Having international investors or lenders is a technique for discouraging local governments from breaking their agreements. All projects analyzed have such involvement.

Most BOT projects require political support to be successful. The Shajiao B Power Project has an influential Chinese champion who promoted the project. The Paiton I Power Plant has investors who have direct political connections with the Indonesian government. The political risks can be reduced by obtaining government support, government guarantees, clear contract provisions, or insurance from appropriate authorities. These strategies help project sponsors obtain economical financing options.

Financing Strategies for High Financial Risk

Financing strategies that sponsors selected to mitigate the financial risks were use of international lending institutions, use of fixed-rate financing, denominating loans in local currency, and denominating a portion of the revenue in foreign currencies. Loans from international lending institutions usually have low interest rates and relatively flexible terms and conditions to assist the development of developing countries. Acquiring debt financing with a fixed-rate is a mitigation strategy. Fixed-rate debt hedges the interest rate risk. Fixed rates may be higher, and they limit the opportunity to take advantage of interest rate reductions.

When project revenues are dominated in local currency, structuring local currency loans to match the revenues will reduce the risk from future exchange rate fluctuation. Currency exchange fluctuation has adversely affected the performance of the North-South Highway and the Paiton I Power Plant. International lenders generally do not want to assume the exchange rate risk unless they are compensated with higher interest rates. Project sponsors, therefore, need to seek local lenders or structure their debt to mitigate such risk.

Structuring revenues in both local and foreign currencies is a technique for mitigating currency exchange rate risks. The foreign currency-dominated portions of project revenues will be used to repay the foreign loans. This strategy is applicable to power projects, since their revenues come from contracts with the host government, and may be used in special cases for transportation projects.

Financial Strategies for High Market Risk

Transportation projects generally are more exposed to revenue risks than are power plant projects, since power plant concession agreements usually include a fixed capacity fee paid by the government entity. Transportation project sponsors have the risk relating to whether or not the anticipated traffic volume will be achieved during the concession period. Power plant projects may subjected to fuel cost escalation while their revenues are subjected to government control. In case of cash deficiency due to underestimated revenues, refinancing and debt restructuring are usually necessary, as was the case with the Paiton I Power Plant.

CONCLUSIONS

The financing of a BOT project depends on the anticipated financial performance of the project. Investors and lenders consider the project's revenues as the source of dividends on equity and repayment of debt. BOT projects tend to be heavily leveraged while ensuring sufficient sponsor equity to demonstrate a high commitment to the granting authority. In structuring the debt financing, the project sponsor strives to acquire long-term, fixed-rate loans to minimize the need to refinance the debt. Initial injection of equity is commonly used to finance the risky construction phase. Once construction is completed, long-term, fixed-rate debt is used to refinance much of the initial equity. Sponsors of low-risk projects have many options, while those on high-risk projects need to be more selective in the selection of financing strategies. Sponsors should seek government and major international financial institution participation if there is high political risk. If the project is exposed to significant financial risk, the debt should be denominated in the same currency as the revenues to avoid currency exchange rate exposure. Fixed-rate loans from major international financial institutions will minimize the inflation risk. If the project is exposed to significant market risk, the sponsor should arrange contingency credit facilities to cover unanticipated revenue shortfalls.

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Use of Award Fees on Lump-Sum Contracts

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ABSTRACT

Most public projects are procured using lump-sum contracts after the project designs have been completed. Awarding the contracts to the lowest responsive, responsible bidder does not always result in best-value projects. Award fees may be used when the owner wishes to provide an incentive for improved contractor performance. This paper examines the award fee procedures used by the General Services Administration in the Pacific Northwest and the results that they have obtained by use of award fees.

INTRODUCTION

For much of the past century, the primary procurement strategy for public projects has been design-bid-build using lump-sum construction contracts. Using the lowest responsive, responsible bidder did not always result in best-value projects. Award fees may be used when the owner wishes to motivate a contractor to achieve desired project objectives. Such fees have long been used in many cost-plus contracts and facilities operation and maintenance contracts. Little has been written regarding the use of award fees on lump-sum contracts.

The Northwest/Arctic Region of General Services Administration has been using award fees on lump-sum contracts to motivate contractors to perform well and emphasize key areas of management concern. These award fees range from ½ to 3 percent of the contract amount. The fee that a contractor earns is based on the owner's evaluation of the contractor's performance on the project. Typical performance criteria include quality, timeliness, technical integrity, and cost-effective management. This paper examines the procedures used by the General Services Administration and analyzes the results obtained on their projects. The agency has seen a significant reduction in the number of claims on projects that were constructed with contracts that contained award fee provisions.

AWARD FEES IN LUMP-SUM CONTRACTS

Award fees may be used in lump-sum contracts when the owner wishes to motivate a contractor to exceed minimum contractual requirements. Such contracts specify a lump-sum price for the construction of the project described in the contract plans and specifications. The award fee is an additional fee the contractor can earn based on the owner's evaluation of the contractor's performance. Contracts with award fee provisions list the criteria the owner will use in making the performance evaluations and the frequency of the evaluations. Typical award fee contract provisions state that the amount of fee the contractor earns each evaluation period will be made by the owner and that the owner's decision is not subject to the *disputes* provisions of the contract.

EVALUATION PROCEDURES

Contractor performance is evaluated at predetermined intervals throughout the duration of the project. Evaluation intervals may be calendar-based, such as quarterly, or construction-based, such as when the project is 25%, 50%, 75%, and 100% complete. Award fee monitors typically are selected by the owner to perform these periodic evaluations using a set of criteria that was specified in the contract solicitation. The amount of the award fee earned for a specific evaluation period may range from no fee to the maximum amount for that period. Construction contracts that contain award fee provisions typically specify the total award fee that the contractor may earn and the maximum award fee that may be earned each evaluation period. For example, the contract may state that the maximum award fee the contractor may earn is $200,000 and that the maximum fee for each of four evaluation periods is $50,000. Some contracts allow unearned fee amounts to be carried over to succeeding evaluation periods, while other contracts do not allow carry over.

The general contractor, the fee monitors, and the owner generally participate in periodic award fee meetings. The fee monitors' evaluations are discussed, and the owner decides the amount of the fee that is to be awarded. The contractor may be required to submit a self-assessment of its performance to the fee monitors and the owner prior to each meeting. The owner's decision regarding the amount of award fee earned each evaluation period is final and is not subject to protest by the contractor. The owner generally provides the contractor feedback regarding its performance after each evaluation period to motivate the contractor to improve its performance.

EVALUATION CRITERIA

The specific criteria to be used by the owner in evaluating the contractor's performance should be contained in the initial contract solicitation. Weighting factors may be used to establish the relative importance of each criterion, and the weighting factors may be changed during the execution of the project. For example, criteria relating to close-out documentation may be assigned a weight of zero during early evaluation periods and a significant value during later evaluation periods.

Evaluation criteria typically used by the Northwest/Arctic Region of the General Services Administration for project coordination are:

- Coordination drawings
- Coordination of trades
- Coordination with other contractors
- Coordination/partnering meetings
- Performance of administration and supervisory personnel
- Tradespersons and workmanship standards
- Cleaning and protection of work
- Submittals
- Schedules
- Quality control
- Safety and health

Evaluation criteria used for project closeout are:

- Substantial completion
- Final acceptance
- Operation and maintenance training

- Final cleaning
- Record documents
- Operation and maintenance manuals

GENERAL SERVICES ADMINISTRATION EXPERIENCE

The Northwest/Arctic Region completed five projects between 1996 and 2000 that were constructed using fixed price contracts that contained award fee provisions. The projects ranged in size from $1.3 million to $13.7 million. Two of the projects were for new construction and three were for repair and alteration. Specific award fee evaluation criteria were included in the contract solicitations, and six evaluation periods were identified. An example evaluation matrix is shown in Table 1 to illustrate the criteria weighting used.

Evaluation monitors were used to evaluate contractor performance immediately following the completion of 10%, 30%, 50%, 75% and 90% progress payments and immediately before the final payment. The award fee pool was divided into six allotments, which represented the maximum award fee the contractor could earn for each evaluation period. The allotment for each of the first five evaluation periods was $40,000 and for the sixth evaluation period was $80,000. Each evaluation criterion was scored using the scale shown in Table 2.

Table 1 Sample Award Fee Evaluation Matrix

Evaluation Criteria	Evaluation Periods					
	10%	30%	50%	75%	90%	Final
Project coordination						
Coordination drawings	10	10	10	10	10	
Coordination of trades	8	8	8	8	8	
Coordination/partnering meetings	7	7	7	7	7	
Admin/supervisory personnel	10	10	10	10	10	
Trades/workmanship	12	12	12	12	12	
Cleaning and protection	5	5	5	5	5	
Submittals	10	10	10	10	10	
Scheduling	13	13	13	13	13	10
Quality control	10	10	10	10	10	
Safety and health	5	5	5	5	5	5
Project close-out						
Substantial completion						10
Final acceptance						15
Training						10
Operating instructions						10
Cleaning						10
Record documents						10
O and M manuals						10
Contract modifications	5	5	5	5	10	10
Totals	95	95	95	95	100	100

Table 2 Evaluation Criteria Ratings

Rating	Points Assigned
Excellent	4
Very good	3
Good	2
Marginal	1
Less than marginal	0

The rating for each criterion was multiplied by the appropriate weighting factor and the results summed to determine the total number of points earned for the rating period. The total number of points earned was divided by the maximum number of points that could have been earned for the period, and the resulting percentage was multiplied by the maximum fee for the period to determine the amount of the award fee that was earned. The average percentage of the maximum award fee earned on the five contracts was 97 percent (it ranged from 94 to 99 percent). There were no claims on any of the projects completed using the award fee, which compares to an average General Services Administration claim rate of 5 percent on fixed price contracts without award fees.

The general contractors' project managers on the five projects were interviewed to determine their perspectives regarding the use of award fees. All the project managers stated that their bids reflected a reduction in profit, which they assumed they could recoup by earning the award fee. This provided a strong motivation for the contractors to strive to satisfy the General Services Administration. The project managers also stated that the award fee provisions and periodic evaluations resulted in better coordination and a better team approach to project execution. The government project managers on the five project also were interviewed, and they stated that the use of the award fee and periodic meetings led to improved communications and trust among the project participants.

CONCLUSIONS

The Northwest/Arctic Region of the General Services Administration has successfully used award fees on fixed price construction contracts. They recently have awarded a \$150 million contract for the construction of a new federal courthouse in Seattle. The contract provides for a maximum award fee of \$1 million that may be earned by the contractor. The government agency has found that the use of award fees provides effective incentives for contractors to exceed minimal contract requirements, eliminate claims, and achieve the owner's project objectives. For award fees to be effective, project owners must identify specific criteria that are important to them early in the contract solicitation phase.

Contractors must understand what is expected of them when they submit their bids for contracts that have award fee provisions. An award fee can be an effective contract management tool if contractors understand the evaluation criteria and believe that they will be evaluated fairly.

Developing a system for assessing the costs associated with different procurement routes in the construction industry

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ABSTRACT

In developing techniques for monitoring the costs associated with different procurement routes, the central task is disentangling the various project costs incurred by organizations taking part in construction projects. While all firms are familiar with the need to analyse their own costs, it is unusual to apply the same kind of analysis to projects. The purpose of this research is to examine the claims that new ways of working such as strategic alliancing and partnering bring positive business benefits. This requires that costs associated with marketing, estimating, pricing, negotiation of terms, monitoring of performance and enforcement of contract are collected for a cross-section of projects under differing arrangements, and from those in the supply chain from clients to consultants, contractors, sub-contractors and suppliers. Collaboration with industrial partners forms the basis for developing a research instrument, based on time sheets, which will be relevant for all those taking part in the work. The signs are that costs associated with tendering are highly variable, 1-15%, depending upon what precisely is taken into account. The research to date reveals that there are mechanisms for measuring the costs of transactions and these will generate useful data for subsequent analysis.

Keywords: alliancing, partnering, procurement, tendering, transaction costs.

INTRODUCTION

The purpose of this project is to identify how clients award work, and how contractors and consultants obtain work and to explore the costs associated with different tendering approaches and contractual and non-contractual arrangements for collaboration. There are three types of cost involved: pre-tendering (marketing, forming alliances, establishing reputations), tendering (estimating, bidding, negotiating) and post-tendering (monitoring performance, enforcement of contractual obligations, dispute resolution). Together, these involve large amounts of resource, but these resources are typically dealt with as overheads, rather than individually costed. This project is the first attempt, in any industry, to generate empirical data about the costs associated with finding and getting work, and the financial consequences of different approaches. The research involves qualitative approaches, using interviews and focus groups, to develop an understanding of the main issues involved, as well as quantitative approaches, based on time sheets generated and collected by the industrial partners. The involvement of industrial partners in data collection, and their commitment to the project from the outset, overcomes the usual problems that researchers would have in collecting such sensitive and confidential data. We are very lucky in this research to have the full collaboration of a good number of industrial partners who have committed real resources and access to their data. By developing techniques for benchmarking the main indicators of procurement costs, the research will enable all participants in the construction industry to measure improvements in performance and to identify the most advantageous ways of forming project teams, thus increasing value for money.

PREVIOUS WORK IN ASSESSING COSTS

The selection of building contractors usually depends on some form of market competition. In those countries moving away from centrally planned economies, such as China, there is a clear perception that competitive tendering increases the quality and efficiency of contractors' performance (Wang *et al.* 1998). Similarly, in Hong Kong, the move towards fee-bidding for consultancy services seems to be gathering momentum (Ng, Kumaraswamy and Chow 2001).

The selection of consultants may also be subject to competition, although in the UK, this is a relatively recent phenomenon. Connaughton (1994) describes how to apply competitive processes to the selection of consultants, at a time when moves towards fee-bidding were growing increasingly popular. However, there are signs of increasing disenchantment with competition on price, particularly in the UK (Lingard, Hughes and Chinyio 1998, Wong, Holt and Cooper 2000). In Sweden, Svensson (2001) examined the factors that influence the choice of consulting firms for international projects. He found that long-term relationships were at least as important as traditional skill and experience factors. Such research highlights the marketing effort that consulting firms require when obtaining work, although there is no assessment of their costs. It also has resonance with the moves in the UK towards innovative working practices, and away from straight price competition.

This move follows the public sector's discarding of compulsory competitive tendering and replacement with the idea of "best value". The development of the public sector as a leading example of good practice in construction can be traced through a series of reports on the UK construction industry (Latham 1994)

Indeed, the use of compulsory competitive tendering for local authorities led to widespread criticism of lowest-price bidding in the UK. The recent move to "best value" as opposed to "lowest price", following the Local Government Act 1999, should help to avoid the negative effects of fragmentation and duplication in terms of monitoring, supervising and inspecting (Nettleton 2000)

Indications of the high costs of estimating and tendering

Private finance is increasingly popular with governments all over the world, as it reduces the need for them to invest capital in the short term. Grimsey (1997) estimated that in the UK, by 1997, PFI sponsors had spent more than £30m on bidding for approximately 30 schemes. His experience tells us that "[t]here has been an underestimation by all parties of the length of time to negotiate project agreements" (Grimsey and Graham 1997: p. 221). This amount of expenditure seems to form about 1½-3% of the total contract sums involved .

Interestingly, Harrison states that although it is fundamental, obtaining work is not the main objective of the estimating process. Estimating is to do with calculating the probable cost of carrying our work, whereas tendering is a separate process of deciding a price, an important distinction that frequently seems to go unnoticed in many writings on this topic. Harrison also points out that increased accuracy costs more money to achieve, and the cost rises more rapidly than the increase in accuracy. The only other thing that he says about the costs involved is that skilled estimators are scarce and expensive.

Anumba and Evbuomwam (1997) highlight the high costs of tendering and mention calls for clients to pay tendering costs to unsuccessful bidders, but they have no suggestion as to how the cost of tendering might be quantified. Similarly, Wåhlström acknowledges the amount of work and time involved in producing tenders but does not quantify the resources. Bunn states that it is important to understand costs associated with tendering.

The best estimates that seem to be available for the overall costs of tendering were reported as from ½-1% of turnover for the simple costs of estimating, right up to 15% if all of the unnecessary costs associated with competitive tendering are taken into account . While these are just estimates, the principle that competition may be organized wastefully is frequently espoused in the literature (see, for example, Pasquire and Collins 1996)

Disentangling the overheads

Commercial practice tends to group the costs associated with tendering into overheads, which are then recouped within the prices charged for work, by simply adding a relevant proportion to costs, along with an allowance for profit. It is these overheads that we have to disentangle in order to tease out the costs of transactions, and the impact of alternative ways of arranging transactions.

Numerous studies have examined various aspects of the commercial process in construction contracting. Uher (1996), examined cost estimating practices in the Australian construction industry. Although primarily concerned with contractors' approaches to estimating, rather than the costs of the approaches, his conclusions are interesting. Clearly, estimators rely heavily on subjective assessments and any attempts to get them to change their approach will need to focus on cultural and attitudinal considerations. A similar finding came from Akintoye , who undertook a survey of 84 UK contractors of varying sizes, looking for factors that might influence estimating practice. The complexity of the estimating process was confirmed, but there was no assessment of the costs. In a later report from the same study , the techniques by which estimates are prepared were examined, again with no attempt to look at costs. However, it is relevant that many different persons are involved in the estimating process. Large firms have estimating departments, but in addition the following may be involved: sub-contractors, managing director, contracts managers, quantity surveyors, site managers, store managers/buyers, planning or programming engineers, commercial managers, design engineers, suppliers, cost planners and insurance assessors. Thus, in collecting data from contractors, it is important to find out who is involved in each estimating process so that the relevant resource data can be identified and collected.

Bajaj, Oluwoye and Lenard (1997) undertook a small opinion survey of 19 contractors in NSW, Australia, about their approaches to risk identification during the tendering and estimating processes. There was no attempt to assess the resources expended in risk identification, the purpose being to ascertain the variety of approaches taken.

Transaction cost economics

Chang and Ive (2001) have undertaken an analysis of transaction costs in construction, but their objectives are to ascertain the most effective way of organizing the market relationships. Indeed, they consciously avoid any attempts to measure directly the costs of different configurations, rejecting this approach as too cumbersome. In this, they follow the example of other transaction cost theorists, such as Masden *et al.* (1991) whose empirical study relied on selecting a limited number variables and asking respondents to give an ordinal score to the importance of each factor. This they did in relation to 74 observations from one firm involved with a shipbuilding contract. These qualitative evaluations were analysed using econometric methods to test various hypotheses about the integration decision. The limitations of this approach are connected with using proxies for data instead of real cost data, and with studying only a small sample of decisions from one firm. There are too many approximations in their data for their conclusions to be reliable, even within the limited parameters of their study. They identify the difficulty of obtaining data as the key obstacle to testing transaction-cost theory. It seems clear that, in studying the relative costs of different ways of working in the construction industry, an approach concerned with proving or disproving transaction-cost theory is not particularly helpful.

The impacts of tendering processes on working practices

There are some notable exceptions to the general trend of ignoring the costs of undertaking business in the construction industry. Becker (1993) in considering the costs associated with the standard general conditions of contract, addressed the impact that contract clauses can have on a contract price. Although the research that led to them is not explained in the paper, his findings are interesting. For example: as risk is shifted from the owner to the contractor, the contractor will increase its indirect cost, contingencies and profit margins to cover the unknown conditions. There is no attempt to quantify the scale of the cost associated with the chosen contractual terms. But these findings point up some useful ideas about the consequences of different ways of doing business in construction. Most importantly, these assertions mean that any meaningful findings about the costs of tendering must also take account of the costs of contract supervision.

In relation to PFI projects, it has been noted that "traditional [contracting] arrangements primarily relied on standardized contract forms that allowed for the swift award of contracts at the expense of costly dispute resolution later in the process" (Grimsey and Graham 1997: p. 218), a comment that illustrates the clear inter-relationships between the various stages of a contract and the impact that economies in one stage can have on later stages. Thus, comparisons of different ways of working need also to take account of the costs of claims and disputes.

The impact of partnering was considered by Matthews (1996), who undertook one case study in which the client, the main contractor and the sub-contractors (although not the consultants) felt that partnering would lead to lower tendering costs. Pasquire and Collins (1996) looked at the effect of competitive tendering on value. Their findings on the lengths of tender lists for traditional and design-build contracts showed that there was a lot of wasted effort in terms of abortive tendering costs for contractors, particularly in the case of design and build. From their sample, 65% of the contractors would be prepared to submit a non-competitive price (cover bid), but there is no detail and the actual incidence of cover prices.

This work hints at huge costs concealed within the tendering processes, but does not attempt to quantify them

Cover prices

An invitation to submit a bid may involve a contractor who does not want to do the job. It is widely believed that having been invited to submit a bid, failure to submit a bid would result in no further invitations to bid, effectively being struck of tender lists. It is not clear why this should be so, but the typical response of a contractor who does not wish to win a project for which it has been invited to bid is to submit a "cover price"

Zarkada-Fraser (2000) studies the ethics of collusive tendering, highlighting the problems that might compromise competition or defraud clients. Although collusion may influence the submission of cover prices, which in turn reduce the cost of tendering, there is no quantification of the costs involved. However, we may deduce from this paper that the high costs associated with traditional rendering practices are part of the temptation to collude and if tender costs were not so high, perhaps contractors would be less inclined to submit cover prices.

Attempts at deriving costs

One notable study took a detailed look at the contractor's process of tendering and estimating, using structured systems analysis, data flow diagrams and a data dictionary. "*Considerable resources are being devoted to the preparation of tenders in this way. Any means of improving the efficiency of this process would be very welcome to contractors and to the construction industry as a whole. This paper presents a documentation of methods of tender preparation in the form of a model of the tasks executed.*" While this was not an attempt to find a "typical" tendering process, it illustrated the detailed steps of a particularly complex one (Betts 1990).

There are, of course, some wonderful anecdotes about tendering practices, most of which, of necessity, remain anonymous. For example, in an office development in London the building already on the site had to be demolished as a first step prior to construction. In the main contract, the contractor had allowed about £80,000 for this item, and his description of the work included health and safety statements and the use of proper equipment and so on. However, this contractor sub-contracted the demolition to another, for about £40,000 and he sub-contracted it to someone else who in turn sub-contracted it again. In the end, the demolition contract was carried out over a week-end by two men with a truck, who basically pulled the building down by tying ropes to their truck and literature pulling it over piece by piece. For this, they were paid £8,000. These layers of sub-contracting appear to have cost

90% of the amount that the client paid for this work. Such anecdotes highlight the desperate need for some robust data on this issue.

DATA COLLECTION

At the time of writing, we are about to commence data collection and can report our plans for this important stage of the research. First, we have divided the construction process into four stages, the management costs of which are influenced by each other:

- Stage One is marketing and selling (including pre-qualification for preferred tender lists), the result is an invitation to treat.
- Stage Two is estimating, perhaps with some element of design, and fixing a price (for consultants, defining a fee and terms of engagement): the result is an offer, which may be accepted by the "customer" saying "yes".
- Stage Three is managing the realization of the design, the result is the building.
- Stage Four is claims, enforcement and disputes, the result is the discharge of contractual obligations.

The data we collect about activities of participants relates to the resources expended, i.e. time and other costs. In order to convert the time data into costs, salary information, perhaps in £5,000 ranges could be used. This can be represented as an average hourly rate and can be converted using salary information. Each person will be allocated to a salary band. The on-costs of employment as well as overheads such as office space, telephones, secretarial support must then be added.

This implies that we shall need to discuss the project with a number of different departments or personnel in each firm and then obtain time and other cost data from them. We shall start with someone in the firm to give us an overview of the work done and the organization of the firm and help us to determine the programme of further meetings and data collection.

The interviews to set up the data collection will be structured but free ranging. We are preparing aide-memoires for the conduct of our meetings to ensure that all relevant matters are covered. Taking contractors as an example, it is envisaged that we may wish to interview persons concerned with marketing, estimating and pricing, contract and site management, procurement, personnel, legal matters and design.

Once we get access to time sheet data, and the industrial partners have confirmed that this access will be forthcoming, every quantifiable unit of management time that can be related directly to project work will be required and certain data about the projects to which they relate. This will enable a thorough statistical analysis of the time sheet data, with a view to ascertaining whether there are systematic differences in procurement costs between different ways of working.

For each project about which we collect time-sheet and other resource data, we shall be eliciting a range of project data. The specification of the data required has been developed in conjunction with our industrial partners, the people who will be providing the data in the first instance before we go out to industry for broader data collection.

- **Type of procurement**: phrases such as design-build or construction management tend to cause confusion in data collection, as they mean different things to different people (Simister 1994, Loosemore 1996). Thus, in order to ascertain the important characteristics for each procurement method, more detailed and direct questions will be used, as follows:
    - Nature of relationship (e.g. partnering, competition etc.)
    - Position in relation to other members of the team
    - Degree of sub-contracting (proportion at each level)
    - Extent of contractor's design responsibility
    - Method of payment (e.g. cost reimbursement, fixed price)
- **Tendering arrangements:** The arrangements for the tendering process can have a significant impact on the costs. The average costs of estimating and tendering are generally multiplied by the number of tenderers, although in true design-build, the successful bidder's design is not lost as a tendering cost, but subsequently used in the project. Also, the incidence of cover bids will reduce the overall costs of tendering. Finally, contractors will need to undertake design of temporary works and some kind of pre-planning in order to complete their bids, and these aspects will be included. The main issues pertaining to tendering arrangements are:
    - Number of tenderers

    - Type of process (e.g. open, single-stage, two-stage, negotiation)
    - Nature of documentation (designs, specifications, bills etc.)
    - Type of contract (standard, bespoke etc.)
    - Duration of tender period

- **Type of project:** In seeking to ascertain the impact of different ways of working, we need to be able to isolate the impact of other project variables. For example, short lead-times may result in poorly planned work, and higher Stage Three and Stage Four costs. Also, certain building types may be inherently more difficult to build than others. In order to test for this kind of relationship, we will be seeking data on the following project variables:
    - Value
    - Duration of lead-time before mobilization
    - Duration of project
    - Building type
    - Location
    - Complexity (value per unit area)
- **Type of client:** Finally, it is possible that different types of client will have an impact on the way that work is carried out.
    - Funding (private, public, PFI etc.)
    - Sector (private, public)

For all of these variables, we will be seeking to develop testable hypotheses that can be modelled statistically. For example, we will hypothesize that complex projects increase the costs associated with Stage Two costs. With sufficient data, this relationship can be explored and the hypothesis will be refuted or supported. In a similar way, we shall be testing the impact on procurement costs of the full range of variables listed above.

One aspect for further consideration is the effect of inflation. All prices need to be associated with a date so that they can be indexed, perhaps Retail Price Index, perhaps Tender Price Index.

The data collection will be carried out in two stages. The first stage involves intensive interaction with the industrial partners already committed to the project. During this stage we will be testing and developing our methods. The basic approach to data collection is firms, not projects. By collecting comprehensive data from each firm, and systematically spreading our net to a large number of firms, all procurement types and all stages will be represented. During this initial phase of data collection, the list of variable will be developed, first by interviewing all relevant personnel within each firm, then by testing the data collection methods within the initial batch of firms.

CONCLUSIONS

In undertaking the initial stages of this research, several things have become apparent. First, the complexity of the data collection places significant hurdles in the way of those who wish to undertake research in this area. This is probably why so few attempts have been made at assessing these costs. The quantifications of the costs of tendering that have already been reported in the literature tend to focus on the cost of estimating and bidding, and take no account of the relationship between stages of a project. Moreover, they are drawn from impressionistic estimates, rather than analysis of data. However, the fact that they range from 1% to 15% indicates a strong feeling that there is a lot of expenditure in this area, and the value added by this expenditure is not clear.

For these reasons, this research promises to shed light in this important area of construction business, an area of business that, in any industry, is frequently under-researched. The work undertaken to date in conjunction with the industrial partners shows that the data collection techniques currently being developed are likely to provide the kind of data that can be subject to rigorous analysis, enabling better judgments to be made about the best ways to conduct business in the construction industry.

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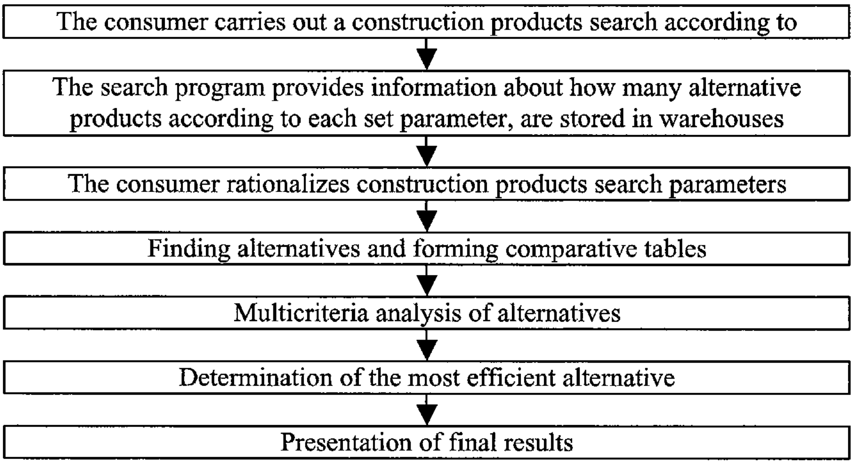

Figure 1 Identification of efficient construction products.

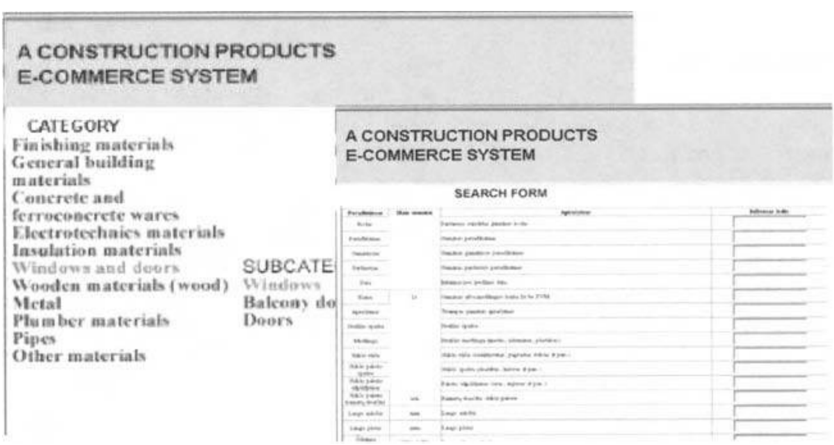

Figure 2 Consumers specify requirements and constraints and the CPMCEC system queries the information of a specific window from a number of online suppliers.

Prekės kodas: H3

Prekės pavadinimas: Virtuvės langas3

Gaminiai iš PVC (polivinilchlorido) profilių jau daug metų populiarūs visame pasaulyje dėl savo puikių eksploatacinių, estetinių, techninių ir higieninių savybių. Šiuolaikinių chemikų, fizikų, dizainerių ir konstruktorių pasiekimai nepaprastai išplėtė gaminių iš PVC profilių panaudojimo galimybes.

Mūsų bendrovė naudoja ypač modernias Vokietijos koncerno SCHÜCO profilių sistemas.

SCHÜCO profilių gaminiai konstrukciškai gali būti su vidurine sandarinimo tarpine (CORONA MD) arba su išorine sandarinimo tarpine (CORONA AS). Vizualiai iš išorės gaminiai gali būti sutapdintų plokštumų, dalinai pastumtų plokštumų arba šuoliškai pastumtų plokštumų. Nestandartiniams sprendimams gali būti naudojami daugelis įvairių modifikacijų pagrindinių ir papildomų profilių.

CORONA sistemos plastikiniuose nėra aštrių, stačių kampų. Nuo tokio rėmo nuteka lietaus vanduo ir nesikaupia purvas. Toks kontūras atrodo tobulas, o langas - lengvas ir grakštus.

SCHÜCO plastikiniuose languose guminio sandarinimo kraštelis prie stiklo yra palyginti siauras ir nematyti negražaus juodo apvado aplink stiklą.

SCHÜCO profilių sistemos turi tik joms vienai pritaikytą firminę furnitūrą.

Langų hermetiškumas pagal **DIN 18055** yra C klasės.

Šilumos ekonomija atitinka aukščiausią **DIN 4108** reikalavimą ir yra **1** kategorijos.

Figure 3 Conceptual description of the first alternative of window.

Kodas	Pavadinimas	Gamintojas	Pardavėjas	Data	Kaina Lt	Aprašymas	Profilio spalva	Medžiaga	Stiklo rūšis	Stiklo paketo spalva	Stiklo paketo užpildymas	Stiklo paketo kamerų skaičius vnt	Lango aukštis mm	Lango plotis mm	Šilumos laidumas W/(m2*K)	Garso izoliacija dB	Šviesos pralaidumas %
H1	Virtuvės langas1	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	420	Tai vienas iš pigiausių variantų	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
H2	Virtuvės langas2	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	661	Tai taip pat labai populiarus variantas	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
H3	Virtuvės langas3	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	686	Labai patogus naudojimo atžvilgiu	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
H4	Virtuvės langas4	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	637	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
H5	Virtuvės langas5	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	963	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
H6	Virtuvės langas6	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	989	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89
D1	Virtuvės langas1	UAB Doleta	DOLETA UAB Petras Petraitis	2001-07-03	800	Labai geros kokybės langai	Natūrali	Klijuota mediena (pušis)	Selektyvinis	Skaidrus	Argonas	1	1520	1460	1.1	32	0.77

Figure 4 Five suppliers have been found after making a search of required alternative windows.

Kodas	Pavadinimas	Gamintojas	Pardavėjas	Data	Kaina Lt	Aprašymas	Profilio spalva	Medžiaga	Stiklo rūšis	Stiklo paketo spalva	Stiklo paketo užpildymas	Stiklo paketo kamerų skaičius vnt	Lango aukštis mm	Lango plotis mm	Šilumos laidumas W/(m2*K)	Garso izoliacija dB	Šviesos pralaidumas %	Šviesos atspind %
H1	Virtuvės langas1	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	420	Tai vienas iš pigiausių variantų	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.0
H4	Virtuvės langas4	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	637	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.0
H2	Virtuvės langas2	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	661	Tai taip pat labai populiarus variantas	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.0
H3	Virtuvės langas3	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	686	Labai patogus naudojimo atžvilgiu	Balta	Plastikas	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.0
H5	Virtuvės langas5	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	963	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.0
H6	Virtuvės langas6	UAB Hronas	HRONAS UAB Petras Petraitis	2001-07-02	989	Patvaresnis profilis	Balta	Plastikas dengtas aliuminiu	Paprastas stiklas	Bespalvis	Oras	1	1520	1460	2.8	28	0.89	0.0
D1	Virtuvės langas1	UAB Doleta	DOLETA UAB Petras Petraitis	2001-07-03	800	Labai geros kokybės langai	Natūrali	Klijuota mediena (pušis)	Selektyvinis	Skaidrus	Argonas	1	1520	1460	1.1	32	0.77	0.1

Figure 5 Multiple criteria analysis of window alternatives and selection of most efficient ones.

Supply Chain Management Aspects for Top Quality Industrial Construction

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Industrial construction comprising high level of prefabricated components together with standardized delivery processes have been some of the main parts of great promise for top quality construction with minimal variances. This paper shall first provide a general presentation of the overall industrial housing solution concept proposed as a result from FutureHome-project that was a major 3-year European Union research and development project. The solution is based on the modular construction, mass customization and industrial production of building modules. Second, the main part of the paper covers the presentation and discussion on the management system for the proposed housing delivery system. Standardized supply-chain processes have been considered as the most important characteristic of the target delivery system. It is likely that the standardized processes lead towards less variances in performance and improved quality compared with the current practice. The developed solutions are enablers for standardized supply-chain processes.

INTRODUCTION

The modern construction delivery is an interplay between many companies and their people. This interplay culminates in site operations where the final product gets its form and is finalized. In this the share of prefabricated parts and package deliveries including building parts and their assemblies has been increasing continually. Practically this means that there exists a continuous flow of new companies and their workers coming or leaving the construction site. In this situation the major challenge for the site management is to identify and eliminate in a pro-active manner all possible disturbances that would affect the performance of the flow of planned work.

The described flow of people and material can be characterized as a supply chain. Christopher (1992) has defined the supply chain as 'the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer'. The leading objective is to increase transparency and alignment of the supply chain's co-ordination and configuration, regardless of functional or corporate boundaries.

This paper presents supply chain management principles that are considered to make an important contribution to construction management practice. Having these principles as a foundation, a set of tools have been developed and tested in live construction project for their validation. The proposed tools to be presented in this paper cover i) modeling and standardization of supply chain processes, ii) the analysis of modular building products for their design, production and assemblies, and iii) planning and control of site processes.

The research results presented in this paper originate from a 3-year European Union funded research and development project bringing together 15 partners in six European countries. This project, called FutureHome, focused on house building technologies to enable the production of affordable, high quality homes. The main part of the project program addressed the development of new building concepts and required technical solutions. Additionally, the project covered management system development for the required new delivery process. FutureHome project was finished in February 2002. A public FutureHome -website can be found at http://www.cv.ic.ac.uk/futurehome.

MODULAR SOLUTION FOR MODERN HOUSING CONSTRUCTION

In the FutureHome project the research and development effort addressed an overall housing solution concept based on modular construction, mass customization and industrial production of building modules. The solution has emerged from studies that have covered many related technologies and information sources. These are

- housing demand estimates in Europe,
- building system concepts that can take advantage of advanced manufacturing systems and methods,
- physical connectors between building components,

- autonomous mechatronic systems,
- IT infrastructure and its components,
- process planning and its management for off-site prefabrication plants and for field factory production and assembly, and
- leaner design and construction processes, focus on value for money, improved productivity, maintainability and sustainability.

The demonstration building, the realization of which was one of the project's main concluding activities, brings together and displays the use of many of the project's results in one package. The FutureHome demonstration building, designed by Corus plc. (UK) and Dragados Y Construcciónes SA (Spain) comprises single-family accommodation over three floors. It may be either detached (no physical connection to neighboring houses), or terraced (connected to neighboring houses with separating walls).

The goal is that the modules of the house can be manufactured in various parts of Europe and these modules fit together using specified connectors. The house comprises of a three-dimensional core module and walls and other building parts that are either connected to the core module or to each other. This one core module extends to each floor. The analyzed house consisted of three stories (Figure 1.1).

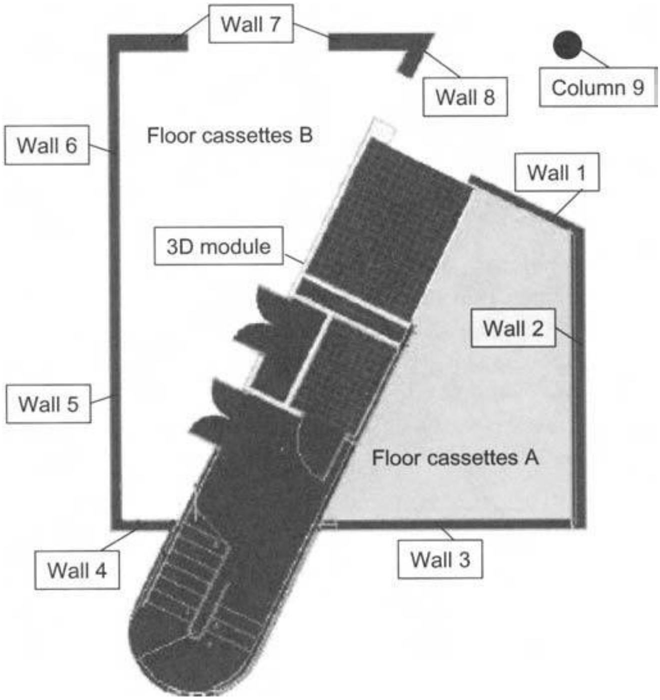

Figure 1.1 Floor layout of the test building.

RELEVANCE AND PRINCIPLES OF SUPPLY CHAIN MANAGEMENT

In industrialized construction, production activities that traditionally have been carried on site are transferred to off site factories. The rationale is simply to avoid the basically inferior conditions on site, or to achieve wider concurrency between activities, which is not possible with site construction with its many technical dependencies (Vrijhoef and Koskela, 2000). This also means that the emphasis in construction project management is transferred to supply chain management because the major part of the construction costs accrues in the supply chain.

However, there is a further issue which makes supply chain management relevant. The goals of low costs and short project duration are especially sensitive to all kinds of disruptions in industrialized construction (Koskela, 2000). All components of a module must be at hand when the factory assembly of modules starts. Missing components and materials lead to delay or costly installation of missing parts to the modules on site. Similarly, regarding site assembly of modules, the modules must be at hand on site in the right sequence for ensuring a speedy assembly. Thus, for achieving the goals of industrialized construction, supply chain issues must be carefully addressed.

The supply chain management principles to be presented next result from an analysis of management principles and trends in different disciplines. An important starting point here is that the system is easy-to-use and facilitates real-time management and monitoring of the supply chain. Other important principles are

- all what can be solved in a project -independent way has been solved (standardized); thus planning and management comprises only project-dependent issues (standardize repetitive processes vs. project planning and management)

- problems are solved in advance, rather than on site (proactive management)

- it is allowable to make errors, but it is not allowable to repeat them (knowledge management practice for learning from past projects)

- continuous updating and improvement of instructions, guidelines and standards (reactive practice)

- early detection of deviation from the plan (instant feedback)

- standardized management of change orders (sound business policy).

Key tools that have been developed based on these principles are presented in the following section.

Components for developing supply chains and their management

Analyzing and understanding supply chain processes

Typical motivations for process modeling are forming of an "as-is" model of the current process, analysis of the current process, forming of the target "to-be" process, and, to have these all results as a common communication tool for training and improvement purpose. In the FutureHome project the delivery chains were modeled and analyzed using the IDEF0 process modeling method.

IDEF0 is a method designed to model the decisions, actions, and activities of an organization or a system. IDEF0 was developed for analyzing and communicating the functional perspective of a system. Effective IDEF0 models help to organize the analysis of a system and to promote good communication between the analyst and the customer. IDEF0 is useful in establishing the scope of an analysis, especially for a functional analysis. As a communication tool, IDEF0 enhances domain expert involvement and consensus decision-making through simplified graphical devices. As an analysis tool, IDEF0 assists the modeler in identifying what functions are performed, what is needed to perform those functions, what the current system does right, and what the current system does wrong. Thus, IDEF0 models are often created as one of the first tasks of a system development effort. (http://www.idef.com).

Within the FutureHome project the IDEF0 was used to describe the to-be supply chain process of the modular housing. The first version of the IDEF0 model was based on generic construction process models presented in the literature (Karhu, 1997) and a real live process by a major pre-fabricated building product supplier, Rautaruukki Ltd. Next, the IDEF0 model was turned into a supply chain schedule. Simulation of the schedule was done for obtaining an improved understanding over the success factors and process variances. Finally the model was generalized in a way that it would be used as a starting point for the development and implementation of advanced delivery processes for modular housing construction (Figure 1.2).

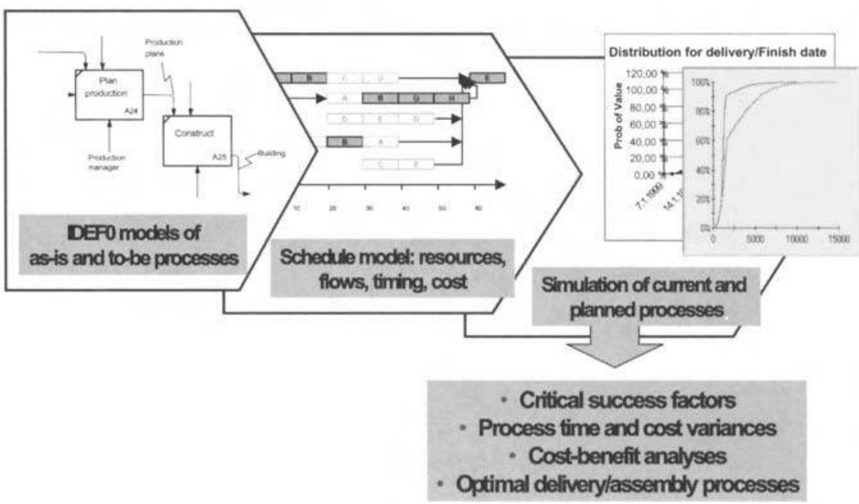

Figure 1.2 The used process modeling approach.

Modular product characteristics and the required design processes

Our trust on the benefits of modularization and modular products is based on the fact that a bigger share of needed work shall be carried in a factory and thus any modular building part will be less vulnerable for defects and disturbances caused by the construction site operations. On the other hand these modular building parts are different components than we are used to in traditional construction. It seemed necessary to have an approach and tool for understanding the characteristics of modular products and how these characteristics should be taken into account when planning design and assembly operations.

The method selected for analyzing modular products is DSM (design structure matrix) that was introduced by Donald Steward in 1981 (Steward, 1981). Using this method one first prepares the model of the system to be studied. This model comprises objects (components, tasks, people or parameters) and the dependencies between objects. The dependencies can be classified for example according to their priority or their main characteristics. Basically the DSM method is also a graphical technique for system modeling. The objects are shown in a matrix form with their dependencies. Dependencies between components are marked in the matrix cells. After inputting all necessary data, the matrix is rearranged using a special partitioning algorithm for sorting the objects and for identifying problematic clusters of objects, for example a set of components having complex dependencies between each other and thus needing special managerial attention.

Since the DSM method can be used for modeling different kind of systems it can be used for different purposes. Up till today it has been used as a technical system analysis tool and a project management tool. When using the DSM method for analyzing technical systems it provides a compact presentation of the system characteristics by capturing the various connections (e.g. soft and hard dependencies) between system elements. As a project management tool it presents the dependencies between tasks and their relative importance in the terms of complexity of dependencies around particular tasks. This DSM representation results in a more feasible schedule for the design activities.

Two main present ways of using the DSM method are summarized in the following:

1. Task-based DSM for project management:

The algorithm determines the order in which activities have to be carried out based on their dependencies. The end result is a sequence of activities according to which the design process proceeds optimally with respect to information exchange.

2. Product architecture based DSM for analyzing technical systems:

The algorithm sorts the components in a way that enables the analyses over potential product chunks (modules), interfaces between them and integrative components.

In the FutureHome project the DSM method was used for analyzing the product architecture and creating the assembly schedule of the FutureHome test building (Figure 1.1). The product architecture analysis indicated that the modules were highly interconnected. This might lead to problems e.g. during the site assembly of the modules. Also the further development of the total product suffers from big number of interfaces between modules. For reducing interfaces, that is reaching a higher level of independence, some changes especially to the third floor were suggested. Figure 1.3 shows the improved product architecture based on the DSM analysis.

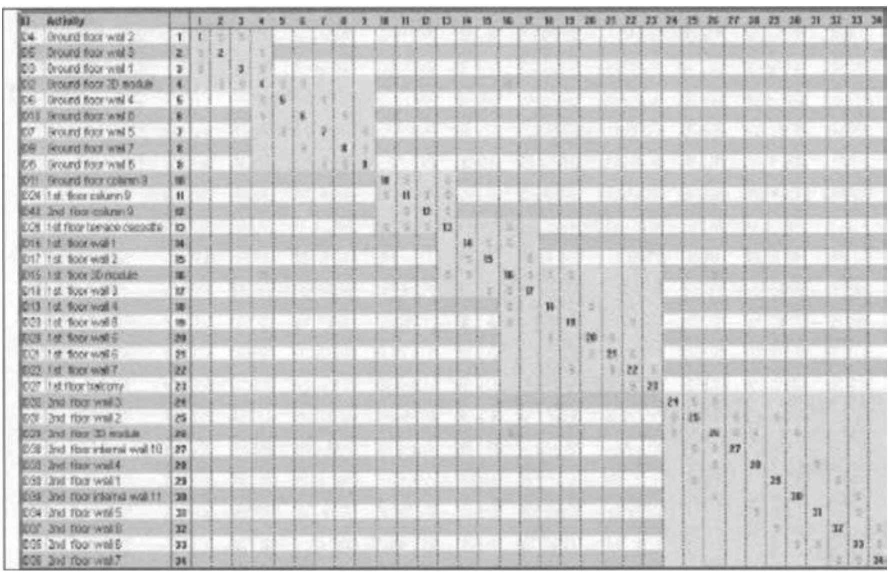

Figure 1.3 The improved product architecture of the FutureHome test building based on the DSM analysis.

Additionally the site assembly plan was prepared using DSM. The predecessors and successors of each component were marked into the DSM matrix. Furthermore the times needed to complete each task were input to the model. After this the matrix was rearranged to find out the optimal assembly sequence. Next, this information was transferred to a project management software package. By means of the project management software the critical path can be made visual based on the information exported from the DSM.

Last Planner method for construction production control and improvement

Construction plans are often deficient in terms of managing the actual flow of work on site. We do not have a common practice of getting all necessary people and their knowledge, e.g different special subcontractors, involved in a flexible way for preparing detailed plans for their tasks in a way which would be beneficial for the overall project performance. Consequently, the plans than can be achieved in the traditional approach can provide only quantitative data on needed work ??together with general information about the sequence of activities and about the most important milestones.

A new method, called Last Planner, to cope with the situation described above has been developed by Ballard and Howell (1998) since 1992. There are five basic principles in this method.

1. The first principle is that the assignments should be sound regarding their prerequisites. Ronen (1992) has also called this principle the Complete Kit. The Complete Kit suggests that work should not start until all the items required for completion of a job are available. Thus, this principle pursues the minimization of work in suboptimal conditions.

2. The second principle is that the realization of assignments is measured and monitored. The related metrics, Percent Plan Complete (PPC), is the number of planned activities completed, divided by the total number of planned activities, and expressed as a percentage. This focus on plan realization diminishes the risk of variability propagation to downstream flows and tasks.

3. Thirdly, causes for non-realization are investigated and those causes are removed. Thus, in fact, continuous, in-process improvement is realized.

4. The fourth principle suggest maintaining a buffer of tasks which are sound for each crew. Thus, if the assigned task turns out to be impossible to carry out, the crew can switch to another task. This principle is instrumental in avoiding lost production (due to starving) or reduced productivity (due to suboptimal conditions).

5. The fifth principle suggests that in lookahead planning (with time horizon of 3-4 weeks), the prerequisites of upcoming assignments are actively made ready. This, in fact, is a pull system (Ballard, 1999) that is instrumental in ensuring that all the prerequisites are available for the

assignments. On the other hand, it ensures that too great material buffers do not emerge on site.

In the FutureHome project, the Last Planner method was applied as a planning and control vehicle for a special subcontractor in charge of installation of steel components. The central tool in the system is the weekly planning and monitoring form. The form provides a tool firstly for preparing the weekly plan, secondly for documenting the hours worked each day and thirdly for monitoring for deviations from the planned actions.

The management cycle follows the idea of the Last Planner (Ballard 2000), however with one major exception. In the Last Planner, the criterion for plan realization is whether a task has been realized during the week in question. However, it turned out that this is too coarse a criterion, when the total duration of an installation might be only two weeks or so. Instead, it was realized that the day's work might be a suitable unit of analysis; the criterion for plan realization is thus whether the day's work, each day, has been realized as planned (i.e. completely and without deviations).

At the present, this system is being implemented across the installation subcontractors of the firm. Thus far, three whole installation projects have been planned and monitored. The percentage of daily tasks realized (completely and without deviations) per week has provided useful information on the conditions on site. The most important causes for non-realization have been ascertained.

DISCUSSION

This paper has presented construction management principles and tools arising from supply chain management. The present performance of construction supply chains provides plenty of potential for significant improvements and business opportunities. As a whole the proposed principles and the tools based on those can form a basis for an improved construction management system. It is likely that following direct benefits will accrue from the implementation and use of this system:

- It will enforce weekly planning and work preparation in the whole supply chain.
- It will promote plan realization and thus plan reliability
- It will make problems visible and it will be easier to act on them

- It will provide a project-independent metric, by means of which the capability of the supply chain can be monitored.

Within the trial carried out in the FutureHome project it was possible to partially validate the potential benefits listed above. However, the findings also show that the full-scale implementation for all expected benefits requires a lot of work. In this, the role of leading project partners, for example clients, big material manufacturers, general contractors and project management companies, is crucial. They are in a position where the contractual relations towards special subcontractors and other key players in the supply chain form the basis for setting requirements for the actual processes and their planning practice. It is important that these key project partners would demonstrate the total benefits that can be achieved with the proposed approach.

CONCLUSIONS

Modern construction operations can gain considerable benefits from the principles arising from supply chain management. At present those principles, and, accordingly the practical management tools based on these principles are not included in daily construction management practice.

The initial experiences indicate that the system developed realizes the benefits envisaged: enhanced understanding on deviation causes, improved planning capability.

ACKNOWLEDGEMENT

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THE IMPACT OF CULTURE, MOTIVATIONAL FACTORS AND ORGANISATIONAL STRUCTURE ON THE UTILISATION AND EXPLOITATION OF IT FOR TEAMWORKING

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ABSTRACT

This paper attempts to contribute to our knowledge of the social aspects of IT usage and exploitation, especially as it pertains to effective and efficient employment of IT for teamworking in design and construction teams. Few will argue the important role and contribution of teamworking in design and construction processes. What is less well understood, however, in this information and knowledge management era, is the social implications of the role IT plays in improving teamworking in construction processes and operations. Although the last ten years has witnessed an upsurge in the amount of materials written in the area of IT in construction, many of these materials have tended to look at IT from a 'hard-nosed' technology perspective. In addition, it is argued that many of these studies have failed to capture the importance of the social dimensions in their quest to produce best practice or guidance documentation. The paper is based on an on-going 2-year EPSRC sponsored research project in the UK, which employs a combination of research approaches, including case studies, ethnographic interviews, semi-structured interviews, postal questionnaires, the analysis of archive documents, and practitioner and researchers' workshops. Organisations from the manufacturing and the financial sectors are also studied and lessons learned documented for the benefits of the construction industry. The paper *concludes that the effect IT has on teamworking varies enormously and can range from being extremely positive to alarmingly negative. This is, in turn, reinforced by the cultural and motivational factors at play within the organisation. These are documented in the paper. Organisational structure, cultural types and specific motivational factors influence the effect IT has on teamworking. The paper recommends that it is vital for organisations to be better able to manage the paradox of increasing speed of communication, which IT could offer, and the reduction in the benefits associated with the sharing and transferring of employee's tacit knowledge. The latter is potentially lost with reduction in face to face interactions in organisations and it is this, which provides the important dynamic capabilities for organisational innovations and competitive advantage. Some understanding of the social imperatives is useful in this regard and is likely to benefit the practitioner community.*

Keywords: *Culture, Information Technology, Motivation, Organisational Structure, Teamworking*

INTRODUCTION

It is generally agreed that we now live and work in an IT era. Indeed, it could be said that, in one form or another, IT suffuses most areas of modern life. Over the past three decades, information technologies in particular have begun to pervade contemporary society and become of more interest to researchers. The contemporary organisation is becoming increasingly complex, not least because of the influx of information technologies. Although the construction industry is historically seen as being relatively slow in its recognition and uptake of IT as a major communications tool, things are definitely starting to move forward. It is certainly the case that the construction industry is starting to become more aware and acquainted with the potential offered by what are referred to as 'Information Communication Technologies' (ICTs). Unfortunately, it also seems to be the case that the IT may be there, ready and available, but that it is not being exploited as fully and completely as it could be. This seems to be the case throughout the industry, across design and construction. This is reflected in both the literature and in practice.

IT, in its different and constantly emerging forms, enables us to undertake activities and achieve outcomes that were not possible before. IT is most commonly perceived as encompassing the computer, its hardware and its software. This is indeed a very prevalent and important IT tool, but it is extremely limiting to think of IT merely in these terms. It is often perceived as being a 'support tool', mainly used to make routine work tasks more efficient. This particularly seems to be the case when we think of IT in the organisational context. However, it is clear as we scan the literature and make organisational observations that IT encompasses so much more. It not only affects the work task but it often has a profound effect on the entire organisation, its processes and its people. Chan (2000) defines IT as "... the convergence of computing, telecommunications and imaging technologies". He further informs us that "in its various manifestations, IT processes data, gathers information, stores collected materials, accumulates knowledge, and expedites communication". It becomes clear, then, as we take a closer look at the subject that IT encompasses much more than just hardware and software designed and utilised to make routine work tasks more efficient. Within the organisational context, IT is becoming increasingly geared towards the enhancement of communication. It is commonplace for today's business organisation to encompass a wide variety of IT 'tools'. Network systems (Internet and Intranet), e-mail, voice mail, video and audio systems, video- and tele-conferencing, and GroupWare are widely available for use in conjunction with word-processors, database, presentation and spreadsheet packages, telephones, and fax machines. Theoretically, it can be argued that this entire package of IT tools will make for a highly integrated and cross-functional organisation, one in which a 'dynamic network of inter-relationships' will enable effective communication to take place (Johnson *et al*, 1998). Amongst all this, however, it is important that we are able to articulate, document and measure the real impact IT contributes to effective teamworking. This is more so when teamworking is increasingly seen as vital for business success and organisational effectiveness (Drew and Coulson-Thomas, 1997). For construction, in particular, it becomes increasingly vital as we move into more collaborative forms of working such as partnering, joint ventures, alliancing, PFI projects and Prime Contracting.

A thorough review of the general IT literature and the literature of IT in construction reveals a vast amount of research undertaken into the role of IT within today's organisation. This is certainly becoming apparent within the construction academic community. However, it remains the case (with a few exceptions) that much of this work is directed towards issues such as the technical aspects and capabilities of IT, its benefits and weaknesses with regard to organisational effectiveness, and the best means by which to measure and assess IT. Little consideration it would seem is given to the 'human factors' associated with IT exploitation. The important and very real issues of teamworking, culture and motivation and organisational structure are often overlooked. The current study, therefore, aims to bridge this gap.

AIMS AND OBJECTIVES OF THE PAPER

The study on which this paper is based is funded by the United Kingdom Engineering and Physical Sciences Research Council (EPSRC). The study's main aims and objectives are:

- To identify the potential of IT to contribute to close integration (including effective communication and collaboration) between clients, design and project team members at all stages during the briefing, design and construction cycle.

- To identify the opportunities for, and barriers to, IT-supported interdisciplinary working (identifying where the non-use, or inappropriate use of available IT tools forms a barrier to effective team working. There may be instances when IT is not appropriate.

- To establish the impact of organisational culture and sub-cultures (team culture and dynamics) on the adoption and exploitation of IT tools in construction, manufacturing and the financial sector.

- To explore the varying motivational factors that encourage the utilisation and exploitation of IT tools in the financial industry (Banking), manufacturing industry, design and in construction with a view to ascertaining what the construction industry can learn from other industrial settings.

The primary aim of this paper, however, is to contribute towards improving our understanding of the complex social dimensions associated with the utilisation and exploitation of information technology in design and construction teams. In doing this, it explores the nature of teamworking within an organisational context. The important factors of culture, motivation and organisational structures that impact upon the exploitation of IT for teamworking are also documented. Whilst it acknowledges the importance of IT as an aid to effectiveness and efficiency, the present study pushes forward the notion that IT affects and is affected by the social and human factors inherent within the organisation.

Research Methodology

The study on which this paper is based is currently being undertaken in collaboration with six organisations representing the construction industry - two architecture practices, a QS & project management firm, a contracting organisation, a financial institution and a manufacturing company. The study employs a combination of research approaches, including case studies, ethnographic interviews, semi-structured interviews, postal questionnaires, the analysis of archive documents, and practitioner and researchers' workshops. To date, 45 interviews (including over 30 in-depth ethnographic interviews) have been conducted in an attempt to gain a real understanding of the often complex IT, teamworking, cultural and motivational issues associated with the utilisation and exploitation of IT for improving teamworking. One hundred and twenty-one usable postal questionnaires (75 from construction, 24 from Manufacturing and 22 from the finance sectors) are being analysed to augment interview analysis.

At this stage, however, tentative findings are emerging which are enabling important understanding and discussion to take place. This will be valuable not only for the research community, but also for those practitioners thinking about IT and its social/cultural/motivational implications. In this paper, however, some of the analysis of the data obtained from the postal questionnaires from the construction industry respondents will be presented.

TEAMWORKING IN DESIGN AND CONSTRUCTION TEAMS

Throughout history, individuals have been coming together in groups in an attempt to make life easier. "Groups are an important instrument of socialisation ... and provide an important source of direction to the individual for understanding social values and norms" (Ingram and Desombre, 1999, pp. 16). Groups are formed for a variety of reasons, but within the organisational context they are generally "... deliberately created by leaders for a specific purpose ... with the aim of implementing plans and achieving objectives" (Ingram and Desombre, 1999, pp. 17). For the present study, this deliberation, purpose and formalisation characterises a 'team'.

Within an organisational context, a team can be defined as a group of individuals working interdependently to achieve a specific objective or attain a particular goal. The team's activity is co-ordinated and each member of that team has a unique role to play or function to carry out which becomes integrated with that of the other members. An effective team is made up of people with different skills and talents. It is generally agreed that the grouping of various people's creativity is one of the team's greatest assets. "In situations that require a combination of multiple skills, experiences and judgements, a team would achieve better results than would individuals working within confined job roles and responsibilities" (Conti and Kleiner, 1997, pp. 26). Although this now appears to be an accepted viewpoint within management and organisational literature, it is only in recent years that organisations have realised the important role teamworking has to play within business and working environments. For the contemporary organisation, "teams have become essential elements in problem solving and in helping businesses move forward into the future" (Conti and Kleiner, 1997, pp. 26).

For all this, however, and for all the attention teams are being given in the literature, organisations and their employees still appear to be failing to get the most out of teamworking. Many are even struggling to come up with a shared definition of 'teamwork'. The authors suggest that when we look at teamworking we must direct our attention not only towards such concepts as skill, purpose and accountability, but also towards the 'softer' issues of communication, inter-relationships, integration and human behaviour. If an organisation and its employees are to gain any benefit from teamworking, it is essential that the whole idea of 'the team' is fully understood. An effective team is made up of individuals who are all aware and supportive of the need for interdependence, and fully comprehend the benefits associated with this level of interaction.

Teamworking certainly has the potential to benefit the organisation. Teams can work well for a number of reasons. Firstly, they bring together complementary skills and experiences. Secondly, in jointly developing clear goals and approaches, teams establish communications that support real time problem solving and initiative. Thirdly, teams provide a unique social dimension that enhances the economic and administrative aspects of work. Finally, teams have more fun, and this is an integral part of their performance (Stewart and Kleiner, 1996, pp. 13). Ideally, then, teamworking is especially suited to activities such as decision-making, communication and implementing change.

In many cases, teamworking is seen as the 'great solution' to communication, decision-making and efficiency problems. Indeed, the six participating organisations in the current study have each demonstrated a commitment to the idea of teamworking within and across all organisational levels. At the senior management level, in particular, it is accepted that propounding 'high-energy' team effort will offer enormous benefits to overall organisational effectiveness. It seems to be the case, however, that too much attention is perhaps being paid to the perceived benefits of teamworking. As Drew and Coulson-Thomas point out, "high-energy team effort has enormous potential. However, the benefits are all-too-often exaggerated and the difficulties underestimated" (1997, pp. 163). Research within the six organisations is beginning to suggest that the desired outcomes of teamworking are high on the agenda, but the means of actually achieving effective teamworking is not being given quite as much attention. In fact, the actual technicalities and procedures associated with team building and teamworking are, it would seem, not given the kind of attention it deserves at strategic levels.

Organisations throughout the construction industry are becoming increasingly complex. This is certainly the case with regard to our six organisations. As a result, those individuals working within the construction industry have to become more adaptable and flexible in their approach to work. This often involves some degree of change, especially when the organisation has little or no experience of dynamic teamworking, if it has traditionally operated within an autocratic or bureaucratic environment, for example. Any sort of organisational change involves a necessary degree of learning and development. It can be suggested that team learning is more effective than individual learning, as knowledge, information and idea sharing is enabled. Drew and Coulson-Thomas support this: "Teamwork is one of the most common prescriptions for coping with change" (1997, pp. 162). Preliminary findings from the current study are suggesting that individuals across the industry, and at all levels, believe in the 'team ethos'. Indeed, it certainly appears to be the case that employees prefer to work in groups and teams rather than on a purely individual basis. Problems arise, however, when different individuals have different notions and ideas about teamwork. It is clear that individuals at different levels and within specific functionaries do perceive and approach the notion of teamworking in certain and atypical ways. Those at the strategic level tend to think about teamworking mainly in terms of efficiency and organisational effectiveness, whilst those at the mid- to lower-levels consider more how teamworking can aid their everyday working practices and procedures.

All those interviewed in the current study regard teamworking as desirable; generally arguing that teamworking is essential. There does not appear to be any significant difference of opinion amongst the different organisations, but attitudes definitely vary at different levels. Basic content analysis has shown that these can be grouped as senior level, mid-management level and lower level. Across the organisations, senior level managers and directors talk about teamworking mainly in strategic terms - teamworking is *regarded* as important and is vital for organisational effectiveness. As we begin to consider the next two levels, though, it becomes clear that teamworking is regarded as essential, but only exists to a *certain extent*. It appears, however, that teamworking often suffers at operational level for one reason or another. IT is often cited as one of those reasons.

The current study is primarily interested in looking at the relationship between IT and teamworking. Therefore, a large part of the ethnographic interview process has been concerned with this and other issues. All those interviewed, regardless of organisation or level, agree that teamworking is important. They also generally agreed that IT is vital to them in carrying out their work. It enables faster and usually more efficient outputs to be generated, and greatly aids their working processes in this way. 'Speed' is definitely the main advantage of IT. When asked to comment on whether IT aids or encourages teamworking, though, many of the interviewees failed to understand and articulate how IT could in any way be related to teamworking. This was less of a problem at the senior level, as those interviewees were able to draw on the official strategic ideal of teamworking and IT. It was more difficult for the other interviewees, though, as teamworking and IT were generally considered to have completely different strengths and weaknesses. When questioned further, interviewees at the middle and lower levels did begin to see how IT and teamworking could be reconciled in an inadvertent way. It was generally agreed that good quality and speedy information was vital to the team if tasks were to be completed effectively and on time. IT is vital in ensuring that this happens. E-mail is deemed particularly useful in this respect.

Communication is a vital part of organisational activity. It can be argued that IT has a central role to play in the communications of the organisation. The expected advantages of IT tools to communication are many. Belmiro, *et al* (2000) state a number of benefits: "... speeding up of communication flow; speeding up of decision making; getting geographically dispersed groups to work together; eliminating departmental borders; sharing databases ...[and] ... eliminating intermediates from the communication process".

The preliminary findings in our study would support Belmiro's statement, but only to a certain extent. Whilst IT certainly appears to speed up communication and decision-making, and allows more people more access to more information, there is a down side. Many of those interviewed feel that 'too much' computer-mediated communication can lead to feelings of alienation and frustration, a point supported by Rozell and Gardner (2000). The use of e-mail is frequently cited as being both indispensable and troublesome. Although it speeds up communication and reduces much of the need for paper, it can cause 'interactional difficulties' (Rozell and Gardner, 2000). It has been suggested that e-mail and other computer mediated systems, such as video-/tele-conferencing, can 'make people lazy' and less likely to partake in face-to-face communication.

THE PERCEIVED INFLUENCE OF CULTURE AND MOTIVATION ON THE EXPLOITATION OF IT TO IMPROVE TEAMWORKING

The movement towards team-based structures with their attendant flatter hierarchies and dispersal of responsibility clashes with tradition" (McHugh and Bennett, 1999, pp 82). Many organisations are moving towards team-based structures without first addressing important cultural implications. The current study has given much consideration to the relationship between teamworking and culture. We define organisational culture as a set of values and beliefs that filter through a specific organisation. This culture affects the behavioural practices within that organisation. Information gleaned from the on-going study would suggest that teamworking, in its different forms, definitely needs specific cultural characteristics if it is to be effective. If the culture of the organisation isn't 'team-oriented', then it is likely that teamworking initiatives or processes will not work well and may even fail. The ethnographic interviews we have conducted into this area, indicate that both organisational and individual beliefs have a crucial effect on teamworking. However, it appears that, to a certain extent, the cultural characteristics of many companies are being overlooked when planning and undertaking various work tasks. Ingram and Desombre are adamant that "co-operation is at the essence of teamworking" (1999, pp. 22). It is essential for successful teamworking, therefore, that the culture of the organisation is as co-operative and open as possible.

It is becoming clear, as our study progresses, that teamworking is regarded as vital for successful task completion. We are also being made aware that a team environment enhances job satisfaction amongst the majority of interviewees. Our study is also trying to find out the extent to which IT can aid or encourage teamworking. This is where difficulties arise, as, at the moment, it seems that IT and teamworking are viewed as two very different concepts amongst the workforce, and it is difficult for many to envisage how the two can be reconciled. It is here that the issue of motivation arises.

In this paper, we posit the view that motivation is a vital concept in bringing about the effective exploitation of IT for teamworking. It is essential that managers at all levels fully understand what motivates their workforce. It can be suggested that if senior-level managers and directors achieve this understanding, then the 'envisaged' culture will become more reconciled with the 'actual' culture. Whether or not people effectively utilise IT for teamworking, depends, to a large extent, on whether they are motivated to do so. The culture of the organisation has to reflect this.

As we speak to individuals at the middle and lower levels, however, confusion once again begins to arise over how IT can aid teamworking. There seems to be a real concern that rather than aiding teamworking, the 'efficiency' culture alienates people, forcing them to sit at their computers and "bang out the goods". This particularly seems to be the case within the large QS & Project Management firm and one of the architecture practices. It is difficult to 'classify' culture or to put an organisation into a 'cultural type'. We are of the opinion that different groups and individuals interpret organisational culture differently. Early findings from our study indicate that at the present time there is a clear gap between what is perceived by those at the top as being the culture of the organisation and those groups that actually work within the organisations. Those at the top need to gain a better understanding of the 'actual' culture and attempt to develop those 'cultural characteristics' that will enable and encourage teamworking and full exploitation of IT.

Table 5.1 presents the data from respondents from the construction industry who completed the postal questionnaires for the study. Respondents were asked to indicate the extent to which certain cultural variables influence their exploitation of IT for teamworking – using the rating scales of 'very high', 'fairly high', 'low' and 'not at all'.

The categories of 'Very high' and 'Fairly high' were combined to form the cultural variables that have the 'most' impact on the exploitation of IT for team working. A closer observation of Table 5.1 reveals that the company's attitude and approach to change and its management and the extent to which creativity and dynamism is encouraged are ranked very highly as having an impact on IT exploitation for improved teamworking. Given the changing business environments and the frequency at which newer and powerful IT tools to aid teamworking come to the market, organisations would need to adapt to such changes and embrace new and relevant IT tools for business use. Also ranked highly as affecting the exploitation of IT for teamworking are the 'atmosphere' within which staff work as well as the degree to which individual initiatives and freedom are encouraged. If the benefits of IT for teamworking are to be realised, a favourable working environment is essential, allowing members of staff to use their initiatives and be creative.

Table 5.1: The extent to which cultural variables influence staff's exploitation of IT for teamworking

		Frequency of Response (Construction Sector)		
Rank	**Cultural variables**	**Very high/Fairly high**	**Low**	**Not at all**
1	The company's attitude and approach to change and its management	34	20	9
2	The extent to which creativity and dynamism is encouraged	33	25	5
3	The leaders' attitudes to the workforce	32	19	11
4	The company's definition of 'success'	32	24	8
5	The general level of commitment amongst the workforce	32	24	8
6	The 'atmosphere' of your working environment	31	24	9
7	The degree to which individual initiatives and freedom are encouraged	31	27	6
8	The level of importance the company places on 'results'	31	27	6
9	The degree to which teamwork, participation and consensus is encouraged	30	25	8
10	The degree to which the company 'invests in people'	29	26	7

11	The degree to which risk taking, experimentation and innovation is encouraged	29	26	8
12	The level of importance on measurable goals and targets	29	29	6
13	The way in which authority and decision-making is approached	25	28	10
14	The level of 'formality' inherent within the company	24	28	11
15	The level of importance attached to stability, predictability and efficiency	24	28	11
16	The degree to which organisation is bound by formal rules and policies	21	31	10

The study also sought to investigate the impact of motivational variables on the exploitation of IT for teamworking. Table 5.2 presents the data from respondents from the construction industry who completed the postal questionnaires for the study. Respondents were asked to indicate the extent to which certain motivational variables influence their exploitation of IT for teamworking – using the scales of 'very high', 'fairly high', 'low' and 'not at all'. Again, the categories of 'Very high' and 'Fairly high' were combined to form the motivational variables that have the 'most' impact on the exploitation of IT for teamworking. An examination of Table 5.2 shows that the probability that work tasks would be made easier and the genuine interest in their jobs are the most compelling motivational variables why staff exploit IT for teamworking. The implication of this result for organisations intending to exploit IT for improved teamworking is that those involved in job design and the matching of skills to job should endeavour to make staff interested in their jobs. They would also need to understand and accommodate the needs and expectations of staff.

Table 5.2: The extent to which motivational variables influence staff's exploitation of IT for teamworking

		Frequency of Response (Construction Sector)		
Rank	**Motivational variables**	**Very high/Fairly high**	**Low**	**Not at all**
1	Probability that work tasks will be made easier	46	11	6
2	Genuine interest in the job	41	13	10
3	Opportunity for personal growth and development	41	18	5
4	The enjoyment and satisfaction derived from the nature of the work itself	37	17	9
5	Opportunity to become specialised and well-trained	36	17	10
6	Opportunity to share knowledge and contribute to the well-being of the company	34	19	10
7	Good leaders, focused and aware of the needs of the workforce	31	22	12
8	The enjoyment gained from working as a group	30	22	11
9	Opportunity to use high quality equipment and software	29	23	11
10	Strong IT department, willing and able to provide an efficient service	27	22	13
11	The desire for job security and stability	27	23	12
12	Opportunity for economic reward (i.e. pay)	27	24	10
13	Opportunity to form social relationships and friendships	20	24	18
14	The desire for affiliation, status and dependency	20	27	13
15	Opportunity for fringe benefits and/or material goods	20	27	16

Staff development is crucial in ensuring a happy and effective workforce, and can go a long way in determining whether IT is exploited to the full. Each of our six organisations has clear-cut official training strategies. However, it was extremely rare to speak to anyone at the middle and lower levels who knew much about this training strategy. Of those interviewees that have actually received any IT training, the emphasis was always placed on the process of using certain packages and how to use them to ensure maximum efficiency. It is vital that employees at all levels feel fully motivated to carry out their work. When the issue of motivation was raised in the interviews, majority of those who felt motivated to Use IT believed that this motivation came from within themselves, and not from the company they worked for. This also supports the views of those who responded to the postal questionnaires.

The majority of interviewees regard IT as speeding up communication and enabling greater dissemination of written data. It is generally agreed that this is vital for overall organisational efficiency. However, it has been asserted by many of the middle and lower level employees interviewed that this 'efficiency' culture takes away a lot of the 'enjoyment of work'. Individuals feels more dispensable than they did, say 3 years ago. Formal teamworking, required to get the job done, works well, but the more informal side of teamworking - the 'face-to-face' communication - can suffer as a result of IT and its inherent efficiency. It is vital for organisations to be better able to manage the paradox of increasing speed of communication, which IT could offer, and the reduction in the benefits associated with the sharing and transferring of employee's tacit knowledge. The latter is potentially lost with reduction in face to face interactions in organisations and it is this, which provides the important dynamic capabilities for organisational innovations and competitive advantage

In summary, it appears that the culture of the organisation largely influences the way IT is taken up and used. The preliminary findings seem to suggest that IT and teamworking are viewed as two very different concepts amongst the workforce, and it is difficult for many to envisage the association between the two. We argue in this paper, that motivation is a vital concept in bringing about the effective exploitation of IT for teamworking. It is essential that managers fully understand what motivates their workforce. We also posit the view that if senior-level managers and directors achieve this understanding, then the 'envisaged' culture will become more reconciled with the 'actual' culture.

ORGANISATIONAL STRUCTURE AND THE EXPLOITATION OF IT FOR TEAMWORKING

The study also attempted to explore the impact of organisational structure on the exploitation of IT for teamworking. Table 6.1 presents the data from respondents from the construction industry who completed the postal questionnaires for the study. Respondents were asked to indicate the extent to which certain constructs of organisational structure influence their exploitation of IT for teamworking – using the scales of 'very high', 'fairly high', 'low' and 'not at all'. The categories of 'Very high' and 'Fairly high' were combined to form the constructs for organisational structure that have the 'most' impact on the exploitation of IT for teamworking. An examination of Table 6.1 reveals that, indeed, organisational structure influences the extent to which IT is exploited in the organisation. Centralisation and complexity are the two most rated constructs. Centralisation refers to the extent to which authority and decision making is concentrated at the top of the organisation.

It is arguable that centralised structures inhibit an individual's capacity to generate ideas and share IT knowledge with others, therefore stifling an organisation's capacity to learn, innovate and exploit IT for teamworking. In addition, a high level of centralisation could restrict channels of communication and reduce the sharing of IT information and expertise. Fostering IT learning and sharing of best practices in an organisational context involves cultivating an environment where IT information and knowledge can be exchanged freely, where structures are flexible and decentralised.

Table 6.1: The impact of organisational structure on staff's exploitation of IT for teamworking

Constructs for Organisational Structure	**Frequency of Response (Construction Sector)**		
	Very high/Fairly high	**Low**	**Not at all**
Centralisation: The extent to which authority and decision making is concentrated at the top of the organisational hierarchy	33	21	11
Complexity: The number of occupational specialisation and task differentiation in the organisation	28	26	13
Formalisation: The degree of emphasis placed on following rules and procedures in role performance	25	29	9
Stratification: The number of status layers or levels within the organisation	21	33	10

Complexity is a measure of the number of occupational specialisation and task differentiation in the organisation. Within project-based industries it is common for organisations to split departmentally or functionally, according to occupational specialisation. In theory, occupational specialisation brings together a host of diverse sources of IT information and knowledge that can be exploited for improved teamworking. However, crossing departmental lines is a challenge and integrating key knowledge sources for improved teamworking requires at best a supportive organisational culture, which fosters collective harmony.

CONCLUSIONS AND RECOMMENDATIONS

The paper has considered the role of information technology in improving teamworking in organisations. Consideration has also been given to the relationship between teamworking and culture. There are many factors that influence the utilisation and exploitation of IT for improved teamworking. These include organisational culture, motivational variables and organisational structure. Organisational culture affects the behavioural practices within organisations. Both organisational and individual beliefs have a crucial effect on teamworking. Organisational structure also influences the exploitation of IT for improved teamworking.

As the application of information technology pervades the way organisations do business, its impact on teamworking will become more obvious. The effect IT has on teamworking varies enormously and can range from being extremely positive to alarmingly negative. It is important for organisations to be better able to manage the paradox of increasing speed of communication, which IT could offer, and the reduction in the benefits associated with the sharing and transferring of employee's tacit knowledge on IT. The latter is potentially lost with reduction in face to face interactions in organisations and it is this, which provides the important dynamic capabilities for organisational innovations and competitive advantage.

There is still a great deal to be uncovered regarding the complex ways IT impacts upon teamworking. This raises interesting challenges for research and for practice. For researchers, there is, therefore, ample scope for further studies to be conducted in the social dimensions of IT. Such studies should explore the role which subcultures and different motivational constructs play in both the utilisation and exploitation of IT in different types of teams in small, medium and large construction enterprises, and bring these issues to the attention of practitioners. There is also an urgent need for empirical study on the impact of professional roles, education & training backgrounds and career path/structure on the exploitation of IT for teamworking.

For the practitioner community, concerted efforts need to be levelled at the extent to which IT training and education is geared towards how IT contributes to teamworking. Similarly, there needs to be some consideration given to the development of appropriate instruments for measuring the quantitative and qualitative benefits of IT for teamworking.

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THE RELEVANCE OF TRADITIONAL FINANCIAL RATIO ANALYSISIN ASSESSING BUSINESS PERFORMANCEAT THE PRESENT TIME

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INTRODUCTION

In December 1994, the British Coal Corporation ("BCC") was privatised. BCC was a public sector company that operated most of the United Kingdom ("UK") coal industry and its privatisation came toward the end of the extensive privatisation programme that had been a central policy of the government. The objective of the policy was to attempt to increase the economic growth rate of the economy.

Immediately prior to the privatisation of BCC, the coal output of the UK coal industry was 51.1 million tonnes per annum. The structure of the industry consisted of one large public sector organisation, i.e. BCC with most of production and second very small private sector companies that cumulatively produced the remaining of annual output. After the privatisation of BCC the structure of the UK coal industry consisted of three identifiable sectors. The first sector was taken by a single large company, RJB Mining Plc (RJB) with an annual output of 36 million tonnes per annum (RJB Mining Plc 1994). The second sector consisted of ten medium-sized companies with a total output of 15.1 million tonnes per annum (N M Rothschild, 1994). Finally, the third sector consisted of the very small companies that had originally operated in the private sector.

The new UK coal industry after December 1994 contained companies that had quotations on the London Stock Exchange ("LSE") and others that were not listed. RJB, the dominant company was listed and there was a combination of listed and unlisted companies in the medium-sized sector.

The performance of the companies attracted significant attention from investor and individual policy makers. As well as the continual search for new investment opportunities, there was the strong interest in the ability of the companies to operate successfully in the energy market with competition from both UK and international suppliers. Prior to privatisation, the UK coal industry performance had been measured principally in terms of physical parameters such as production and productivity. Privatisation introduced performance measurement methods based on financial parameters. The traditional technique for measuring financial performance is by the use of financial ratio analysis.

This study examined the early performance of the medium-sized sector using financial ratio analysis to assess the use of this technique in the particular circumstances of new private sector companies in a highly competitive industry.

STRUCTURE OF THE UK COAL INDUSTRY

After the privatisation of BCC, in December 1994, the UK coal industry was divided into three sectors: first the large-sized coal mining sector, second the medium-sized coal mining sector and third the small-sized coal mining sector.

The large coal mining sector consisted of one company and it has a listing on the LSE. This was called the RJB Mining Plc. ("RJB") at the time of privatisation. The company changed its name to UK Coal Plc on 25th of May 2001. The company had been successful in the purchase of three of the five regions of BCC. The three regions purchased by RJB were in England, apart from one underground mine in North Wales. The other two regions were Scotland and South Wales.

RJB is large on both the domestic and international scale of coal mining operations and its annual output after the privatisation of BCC was 36 million tonnes [N M Rothschild, 1994 and RJB, 1994]. The company currently produces over 20 million tonnes of coal a year, 17 million tonnes from its deep mines and over 4 million tonnes from surface mines. It employs 8,000 people at 40 locations throughout the UK, and almost as many again on contract or in the supply of goods and services [http://www.rjb.co.uk , 2001]

The medium-sized coal mining sector incorporates some companies, which are listed on the stock market and others that are unlisted. In addition, the sizes of the companies vary from significant regional operations with several producing units to single producing units with very few employees. Ten companies have been selected from this sector and their performance after the privatisation of BCC has been assessed (see Appendix A). Five of the companies were unlisted and four of the companies had a quotation on the LSE at the time of privatisation of BCC. One company Midlands Mining was formed after the privatisation date. These companies were chosen because there was a significant amount of available information on which to base a systematic and detailed study. The medium-sized coal mining sectors includes mines producing annual outputs of coal in the range of 0.25 million tonnes and 5.0 million tonnes. The small-sized coal mining sector contains the remaining mines with production size of each below 0.25 million tonnes per annum.

ACCOUNTING RATIOS

Accounting financial ratio analysis is one of the most commonly used methods of assessing the performance of a company used by the analysts, investors, bankers, creditors, and suppliers. The ratio analysis is a very useful way to summarise a large quantity of financial data in the financial statements and convert them into convenient percentages and ratios. The convenience and simplistic nature of this technique makes it attractive but it contains the inherent danger of not highlighting major problems at an early stage.

These percentages and ratios are a convenient way of judging and comparing the current performance with the previous results or forecasts. Also they are useful for comparisons with other similar companies. The performance operating data can be compiled for companies in the same sector or for those in stock market index. For UK listed coal mining companies the appropriate sector for comparison is the Financial Times FT Mineral Extraction Index. Also UK coal mining companies are in the FTSE SmallCap and the FTSE Fledgling [Hemmington Scott, 2000].

Certain accounting numbers in the financial statements require some adjustments to generate ratios that are representative of the actual business performance. These adjustments are very important in order to eliminate any distortions that can be caused by actions such as the goodwill write off or the revaluation of assets. An example of the ratios, that are significantly affected by goodwill, are the return on total assets, the return on total capital employed, the return on equity, the leverage ratios and the earning per share calculations. Writing off goodwill to capital reserve, with no impact on the earnings, produces ratios that give a favourable impression because the full amount of capital employed on the balance sheet is understated and the associated capital costs are ignored in the profit and loss account.

The assessment of business performance using the financial ratios requires the calculation of ratios in successive years. For an individual company, the assessment is based upon the changes in the financial ratios over time and also by comparing the financial ratios with those of other companies. There are four categories of financial ratios used to assess business performance and they are performance ratio, short-term liquidity ratio, leverage ratio and market value ratios. They are described below and their arithmetic formulas are given in appendix B.

Performance Ratios

The performance ratio is regarded as the most important financial ratio in financial statement analysis. It measures the relationship between the profit figure generated during the period in the profit and loss account and the capital invested figure in the balance sheet. The result will show to what extent the company has effectively used its available assets [Salmi, Virtanen and Yli-Olli, 1990].

The most common measures of performance ratios are return on total assets ("ROTA"), return on capital employed ("ROCE") and return on equity ("ROE").

The annual report and accounts should be examined closely to determine if adjustments have been made to write off any goodwill on the BS. In this case the ratios should be calculated on the basis of goodwill written off and also on the basis of goodwill not written off. The second ratio is the most appropriate because it reflects the total amount of capital, which has been used by the company.

Return On Total Assets

The ROTA is used to assess how efficiently the management is utilizing all the assets in the company to generate an operation surplus or profit. Performance is good if the ROTA is higher than the ROTA for company of equal or less risk.

Return On Capital Employed

This measures the profitability on the total long-term capital employed i.e. both debt and equity.

Return On Equity

The ROE measure the profitability from the point of view of shareholders' capital. It measures the relationship between the profit after tax ("PAT") attributable to the shareholders and the owners of the fund expressed as percentage.

Short-term Liquidity Ratio

The short-term liquidity ratio measures the financial position of the company and assesses its ability to meet the immediate liabilities as they arise and thus avoid the possibility of a liquidity crisis. It also focuses the attention of the analyst on the size of company's current liquid assets relative to its maturing current liabilities. It is particularly important to determine if the company is able to avoid bankruptcy at the start of its life

There are two main short-term liquidity ratios are; current ratio and quick ratio.

Current Ratio

This ratio measures the ability of the company current assets to cover its current liabilities without having to raise finance by issuing more shares, selling fixed assets or borrowing money [Laughlin and Gray, 1989a]. In general this ratio should be in the range 1.5 - 2.0.

Quick Ratio

The quick ratio is also known as the "Acid Test" and this ratio attempts to be more conservative than the current ratio in measuring the financial position of the company. When comparing current assets with current liabilities not all of the current assets are assumed to be convertible into cash in very short time without loss. As a result the stocks and work in progress are excluded from the current assets when calculating the quick ratio [Laughlin and Gray, 1989b]. In general, this ratio should be equal to 1.0.

Leverage Ratios

Leverage ratios are used to assess the relationship between the equity and debt, i.e. the degree to which the company relies on debt in financing its operating activities [Hindmarch and Simpson, 1991].

There are different methods for calculating the leverage ratio and this mainly arises due to the different meanings given to the term debt: 1. Long-term loans. 2. Long and short-term loans i.e. all the interest-bearing debt. 3. Long-term loans plus the interest-bearing and non-interest-bearing debt. Trade creditors within current liabilities are an example of non interest-bearing debt.

The danger with a high leverage ratio is that the company will have high interest charges. If these interest payments can not be covered from sales revenue then the company can be forced into liquidation by its creditors. For new mining companies this is a real danger if sales targets are not achieved or geological problems cause a reduction in production and sales.

The annual report and accounts should be examined closely to determine if adjustments have been made to write off any goodwill on the balance sheet. In this case the ratios should be calculated on the basis of goodwill written off and also on the basis of goodwill not written off. The second ratio is the most appropriate because it reflects the total amount of capital which has been used by the company. In the following section different methods of calculating the leverage ratio are explained.

Long-term Interest-bearing Debt

This ratio looks at the relationships between the long-term debt and shareholders' funds. Long-term debt is identified on the balance sheet as creditors more than one year. This is capital raised to finance the long-term activity of the company, has terms of approximately between five years to ten years [Reid and Myddelton, 1996a].

Long and Short-term Interest-bearing Debt

This ratio is the relationship between the long and short-term debt and shareholders' funds and. The short-term debt represents the temporary cash deficit borrowed to finance day-to-day activity.

Long-term Debts Plus Current Liabilities

This ratio is the relationships between the total debt to shareholder funds and total capital. The total debt includes the long-term debt plus current liabilities and total funds includes the entire fund provided to the company either by the owners of the company 'shareholders' and/or the lender 'debtholders' and creditors.

Interest Cover Ratio

This ratio identifies the extent to which the profit before interest and tax ("PBIT") is able to service the interest payments due from the borrowings [Walsh 1996a, Reid and Myddelton, 1996b]. The ratio is very sensitive to both the increases in interest rate and the changes of profitability [Ashton, 1982b].

Market Value Ratios

These ratios can be calculated by using data from the financial statements and from market data. Good performance is measured by comparison with other companies with equal or less risk. Also annual increases demonstrate strong performances.

Earning Per Share

The earning per share ("EPS"), is at the present time the most widely quoted statistics for assessing business performance. It relates the PAT to the number of ordinary shares in issue in the company. The ratio tells us the profit attributable to shareholders for every share held in the company.

Dividend Per Share

Dividend per share ("DPS") represents the fraction of the PAT per share paid out to the shareholders in cash for every share they hold in the company.

Dividend Cover

The ratio measures the number of times the dividend could have been paid out of the profit available for distribution as a dividend to shareholders.

Earnings Yield Ratios

The yield on a share expresses the return it provides in terms of earnings as a percentage of the current share price. The EPS is calculated from the last full year's earnings.

Dividend Yield Ratios

This ratio measure the historic annual dividend paid to a shareholder as a percentage of the current company share price on the stock market.

Price to Earnings Ratio

The Price to Earnings Ratio ("P/E") or "multiple" is the most widely quoted market parameter of share value at the present time and can be calculated on historical or forecast earnings. The ratio is used by the majority of analysts and investors to measure the number of years it would take, at its current level of PAT to earn an amount equal to the market value of share. The historical P/E ratio is calculated daily for quoted companies in the financial media.

Market to Book Ratio

The ratio relates the total market capitalization of the company to the shareholders' funds. To express it in another way, it compares the value in the stock market with shareholders' investment in the company. [Walsh, 1996b].

THE APPLICATION OF FINANCIAL RATIOS

The financial ratio analysis was applied to each of the UK medium-sized coal mining companies in the study over the period 1994- 1997 to attempt to determine those that had the ability to survive in the new competitive market.

The number of annual reports and accounts used in the study for each company for the financial ratio analysis varied significantly (see Appendix A). Some of the companies have operated and produced annual reports and accounts over the full period of study. A second group of companies had started operations before the start of study and ceased operations during the study. A third group of company started and ceased operation during the course of the study. The changes in the structure of the UK medium-sized coal market are shown below in table 1.

Table 1.1 The Changing Structure of the UK Medium-sized Coal Sector

At Start of Study **Companies Name**	**At 1997** **Companies Name**	**At 2001** **Companies Name**
1. Coal Investments Plc.	-	-
2. Consolidated Coal Plc.	Consolidated Coal Plc.	-
3. NSM Plc.	NSM Plc.	-
4. Rackwood Mineral Holdings Plc.	Rackwood Mineral Holdings Plc.	-
5. Celtic Energy Ltd.	Celtic Energy Ltd.	Celtic Energy Ltd.
6. Goitre Tower Anthracite Ltd.	Goitre Tower Anthracite Ltd.	Goitre Tower Anthracite Ltd.
7. Hatfield Coal Company Ltd.	Hatfield Coal Company Ltd.	-
8. Midlands Mining Ltd.	Midlands Mining Ltd.	-
9. Mining (Scotland) Ltd.	Mining (Scotland) Ltd.	Mining (Scotland) Ltd.

10. Monktonhall Mineworkers Ltd.	-	-

The financial ratio analysis for listed companies covered the return on investment, liquidity, leverage and market value ratios. The analysis for unlisted companies covered the first three categories only as they did not have a market value from a Stock Exchange Price.

Several of the companies experienced major financial, marketing and technical difficulties during the period of the study and the negative values generated by the ratios can produce data that are meaningless. For example a negative capital employed, as a consequence of writing off goodwill to reserves, combined with losses in the profit and loss account generates a positive return on capital.

Some companies had very short operating periods prior to going into liquidation or shares being suspended. As a result, it was necessary to use end year data for items such as capital employed and current assets to provide a basis to compare the companies. It is preferable to use the average of the opening and closing values of these items in financial ratios analysis. End year figures may vary significantly from opening balances as a consequence of write off's during the year. Capital employed data, for example, at the end of the year may not be representative of the actual capital employed by the company.

In addition to the problems mentioned above, there is the problem of utilising data extracted directly from the profit and loss account and balance sheet of annual report and accounts. These data are based upon accountancy standards that are not designed to produce information that is directly applicable for assessing company performance in terms of positive operational cash flow generation and creating shareholder value.

From the study, the following comments emerged about the advantage and disadvantages of financial ratio analysis.

ADVANTAGE OF FINANCIAL RATIO ANALYSIS

There are number of advantages from using ratio analysis in assessing company performance:

1. The majority of the calculations can be made quickly and directly from the summarised BS and summarised profit and loss accounts of the published annual reports and accounts of the company.

2. Accounting ratios enable the user to compare companies that cover a wide range of sizes.

3. Comparisons can be made with companies in the same industrial sector and over the whole market.

4. The use of ratios can enable the analyst to relate accounting and non-accounting data. For example, several investor ratios relate accounting data to the share price.

5. The preparation of a small number of key ratios simplifies the examination of the extensive amount of data contained in the annual report and accounts.

DISADVANTAGES OF FINANCIAL RATIO ANALYSIS

Ratio analysis based upon the current accountancy techniques has major limitations for assessing company business performance.

1. The calculations of ratio analysis are based on historical data. The data are not published until three months after the end of the financial year for listed companies and up to ten months for unlisted companies. This long delay means that remedial action may not be taken by shareholders until it is too late.

2. The calculation of ratios is limited to public domain information, which is sometimes not sufficiently detailed.

3. Comparisons of ratios over time between a particular company and other companies are difficult because individual companies, in the same country, may adopt different accountancy policies that are still consistent with the country's accountancy standards.

4. Comparisons between countries are even more difficult as a result of major differences in accountancy standards. In these circumstances major adjustments are required to attempt to put the data on comparable bases.

5. The data on the profit and loss account and balance sheet at the end of the year may not be representative of the position throughout the majority of the year. This situation arises when short-term actions can be taken at the end of the year that improve the financial ratios, but have to be reversed at an early stage in the next financial year. This can be

done by reducing stocks at the end of the year and replacing them at the start of the new financial.

6. Accounting ratios do not take into account the cost of equity capital. Accountancy profit calculations only include the cost of labour, the cost of land and the cost of debt capital.

7. There is insufficient data for the calculations required for ratio analysis for companies that have recently become operational.

8. Comparisons between new companies are difficult when they have different financial year ends. Also new companies, often vary the period covered for the first and second financial year.

9. The method of allowing goodwill to be written off from shareholders funds on the BS with no impact on P&L account, results in financial ratios that are not using appropriate capital employed and profits.

CONCLUSIONS

1. Although ratio analysis is used extensively, it was not a satisfactory basis for assessing the business performance and predicting the ability of company survival of the UK medium-sized coal mining company over the period of the study.

2. The disadvantages associated with financial ratio analysis outweigh the advantages and this has resulted in significant efforts being made to identify more suitable methods for assessing company business performance.

3. External analysts need to have a good understanding of a company's area of business and the company's capabilities if they are to assess the possibility of a company improving from a weak financial position that has been exposed by means of financial ratio analysis.

4. Financial ratio analysis had a limited use for assessing the performance of the UK medium-sized coal mining companies in the initial years after the privatisation of BCC because:

    a. For new companies, the most important indicator for immediate and medium term survival, is a strong positive net cash flow on core coal operations. Financial ratio analysis relies on profit and loss accounts data that are based on profit and its associated non-cash costs and provisions.

b. Financial ratio analysis does not provide data to show the extent to which all the costs of the business are being covered. For example there is no charge in conventional profit accounting for the cost of equity capital.

5. Cash flow analysis techniques and methods to incorporate the cost of equity capital in business performance are increasing in importance to deal with the problems in the use of financial ratio analysis that have been identified in this study.

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APPENDIX A

The UK medium-sized coal mining companies:

1. Coal Investments financial years end 31st March 1994 and 1995.
2. Consolidated Coal financial years end 31st March 1996 and 1997.
3. NSM financial years end 31st March 1995 and 1996.
4. Rackwood financial years end 31st December 1995, 1996 and 1997
5. Celtic financial years end 31st March 1996 and 1997.
6. Goitre Tower financial years end 31st December 1995 and 1996.
7. Hatfield financial years end 30th June 1995 and 1996.
8. Midlands Mining financial year end 31st May 1997 for fifty five weeks.
9. Mining Scotland financial years end 31st March 1996 and 1997.
10. Monktonhall financial years end 30th June 1993, 1994 and 1995.

APPENDIX B

Return on Total Assets = *ROTA / Total Assets * 100*

Return On Capital Employed = *PBIT / Total Assets- Current Liabilities*

Return On Equity = *PAT / Shareholders' Funds * 100*

Current Ratio = *Current Assets / Current Liabilities*

Quick Ratio = *Current Assets - Stock and Work in Progress / Current Liabilities*

Long-term Interest-bearing Debt Ratio = *Long-term Debt / Shareholders' Funds * 100*

Long and Short-term

Interest-bearing Debt Ratio = *Long and Short-term Debt / Shareholders' Funds * 100*

Long-term Debts

Plus Current Liabilities = Total Debt / (Shareholders' Fund + Total Debt) ** 100*

Interest Cover Ratio = *PBIT / Interest Payable = Times*

Earning Per Share = *PAT / Weighted Average Number of Ordinary Shares in Issue during year*

Dividend Per Share = *Dividend / Weighted Average Number of Ordinary Shares in Issues during year*

Dividend Cover = *EPS / DPS = times*

Earnings Yield Ratios Percentage = *Historic EPS / Current Share Price *100*

Dividend Yield Ratios Percentage = *Historic DPS / Current Share Price *100*

Price to Earnings Ratio = *Current Share Price / Historic EPS*

Market to Book Ratio = *Market Capitalization / Total Shareholder Funds*

Knowledge Creation Processes and Dynamics: An Empirical Study of Two Multidisciplinary Project Teams at the Design Phase

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ABSTRACT

This paper examines how knowledge is created across functional boundaries in two multi-disciplinary project teams during the design phase of two construction projects. The two projects under study are an infrastructure development project and a residential development project. The study examines the use of knowledge and learning during problem-solving and decision-making in a project-based work environment. Empirical evidence collected from two multi-disciplinary project teams is used as a means of building a grounded theory of knowledge creation in project teams. This study is based on nine months' observation of the team settings of and interactions among the clients and various construction professionals within these two projects, in-depth semi-structured interviews of all core project team members, and analysis of all relevant project documents. The goal of this paper is to examine the dynamics of two knowledge creation teams in action, identifying contributing processes by describing in detail the ways that two knowledge creation teams function at the project design stage.

INTRODUCTION

Creating new knowledge and perspectives is fundamental to new product development. A new product can be considered as "a package of features and benefits, each of which must be conceived, articulated, designed and 'operationalised', or brought into existence" (Dougherty, 1996, p. 425). The development of a constructed facility can be viewed as a new product development, with customers or end-users purchasing or using the facility. They would assess their own needs and affordability before they purchase. The development of a new product entails the application of knowledge to new problem-oriented situations, thus requiring uncertainty reduction. The same applies to construction projects, with each project unique in itself in terms of design and construction. With the many constraints the construction industry faces (due to limited space, increasing project complexity, limited budgets, tight programmes and the constant demand for facility innovation), project teams are faced with challenges to utilise diverse, and create new, knowledge in meeting stringent requirements and fulfilling ever changing needs. Knowledge creation in projects could also lead to the technological innovation that is so desperately needed in the construction industry (Gann, 2000).

Project team members have to incorporate new information into their understanding in order to solve the technical challenges they face. Thus, learning is inherent in the work they do (Mohrman, Mohrman and Cohen, 1995). The knowledge gained can be explicit and formal, as when members learn new analytical procedures to deal with a new phenomenon or go to a publication to learn the properties of a new material being used for the first time. Alternatively, their work may lead to tacit learning (Polanyi, 1962), occurring as the individual learns from experience and develops a deep but unarticulated sense of the phenomena at hand. It could also lead to informal learning as members consult one another, taking advantage of each other's personal knowledge stocks (Eraut, 2000). Learning can be personal and remain within the heads of individual contributors, or become public when it is shared with others and perhaps systematised.

THEORETICAL BACKGROUND

The technical complexities and multidisciplinary nature of modern capital facility projects require management and execution by highly skilled, task organized project teams. These teams are organizational entities devoted to the integration of specialized knowledge for a common purpose (Cleland, 1995). Team members may include representatives from owner, designer, contractor and other stakeholder organizations. These functions, and thus team composition, vary as a project progresses through its life cycle from business planning through facility operation.

The project team, through sharing collectively, breathes meaning into new ideas in new product development. These new ideas create information systems that will transform the way a sector of society will perform its jobs. When team members have to develop a product from a concept given to them by the customer through a contract, a sharing of knowledge needs to take place in order to ensure that the right design decisions are made by the team.

The environment for group task performance in new product development is usually ambiguous, complex and uncertain. To reduce uncertainty, team members need to communicate by engaging in dialogue. They need to focus on "discussing issues, analysing evidence and ideas, and advancing and refuting knowledge claims" (Salazar, 1996, p.166). Through open dialogue where speaking and listening takes place, they can develop shared understandings and establish a core knowledge base which they will require for integrated product development.

During this dialogical process, team members share with one another their personal or private knowledge (called tacit knowledge) gained through experience. They integrate that private knowledge with the explicit knowledge or learned knowledge that can be easily shared to develop a core knowledge base about the product to be designed (Dixon, 1994). The integration of these diverse perspectives based on the tacit or explicit knowledge of the team membership takes place through communication and learning, and is then transformed into the core knowledge base, which resides in the team.

In addition, through communication, team members construct their own social reality with their mental models and develop a project language around the terminology of their new product. The construction of social reality based on "time and place" becomes an acculturation or a socialization process which demands adaptive skills as learning occurs (Hunt, 1984, p. 169).

RESEARCH METHOD

The main focus of this paper is to explore the underlying processes of knowledge creation in a multidisciplinary project team setting. Taking into account the explorative nature of the study and the complexity of the issues, a more holistic approach has been adopted towards the study of specific phenomena. As a result, two in-depth case studies were used to obtain as thorough a picture as possible of the processes affecting knowledge creation in multidisciplinary project teams.

Fieldwork was carried out within two multidisciplinary project teams, employed by a leading Hong Kong property developer to develop two infrastructure and residential projects. Evidence for the case studies relied on three main sources collected over a 9-month period - project documentation, interviews, and finally direct observation.

CASE STUDY ONE: THE INFRASTRUCTURE PROJECT

Project Background

The case project involves the construction of a complete infrastructure system serving a remote island. It is a very complex project because the developer is effectively building an entire infrastructure that will serve the various phases of a large-scale residential development. The scope of the infrastructure project embraces construction of a new water supply system including a submarine pipeline bringing water from the mainland to the island, a new water main on the mainland to cater for increased water supply due to the new development on the island, a service reservoir, a new water main throughout the development, and a private flushing water system. A storm water drainage system and a sewage system such as sewers, sewage treatment plant and pumping stations/rising mains will be required for the new development. For transportation, a new road system including a slip road connecting to an existing bridge, a toll plaza, island roads, a toll building, and ferry piers on the island for passengers and goods will be constructed. Other ancillary facilities that need to be provided to the island include a refuse transfer facility, gas installation, electricity, telephone, fire station and police station, as well as forming the entire site to the desired contours and landscape. Basically, the design and construction of the infrastructure works will transform the island from a barren or primitive state to a modern facility serving a mini new town to be developed on it, as well as a future theme park.

The project scope has been amended a few times due to the developer anticipating changes in the demands or expectation of the potential buyers. For example, earlier on, a golf course and a big landscape garden with rivers and ponds were proposed, but these were later scrapped when the development was downgraded after the 1997 Asian financial turmoil.

Throughout the design process, besides regular meetings, occasional ad hoc meetings were arranged on special issues that were pertaining to the project at that moment, e.g. piers, seawall, retaining wall, island road. This type of ad hoc meeting is intended to flush out details or concerns among various stakeholders in order to facilitate the smooth progress of the project design. In addition, ad hoc meetings with government officials were also involved so that informal understanding and knowledge sharing could be achieved prior to formal submission. Consultants who have prior knowledge of working with officials usually find this a valuable resource as they have benefited from their past experience of working with them.

The Infrastructure Project Team

The infrastructure project team includes the client's project managers, architects, structural and civil engineers, quantity surveyors, E&M engineers, sewage treatment plant consultants, landscape architects, registered structural engineers (registered under Buildings Department, Hong Kong Special Administrative Region (HKSAR) Government for this project) and structural engineers for the central pier. They are all professionally qualified in their respective professional disciplines.

Some of the team members were appointed by the client as early as in 1992; subsequently, various professionals were appointed to join to the team to provide knowledge input to various aspects of the infrastructure project. However, due to the size and complexity of the project and the extensive negotiations with the government on the master layout plan, the design progress was very slow and has been revised several times to cater for the changing market. During the course of the design development, various team members left their companies or were transferred to other project teams internally within their companies.

Some of the consultants appointed had prior experience in infrastructure projects and contributed to the project by utilizing some of the experience they gained from other projects both locally and overseas. During the course of the design development, they naturally shared their experience and the lessons they had learned from other projects, and other team members were willing to listen to them. Quite often, the shared experience concentrated on "failure stories" or mistakes rather than "success stories", in order to remind other team players not to fall into those "traps" again on this project. Even experienced team members found that this project differed from the past in terms of the engagement of consultants from one government department. In this case, they were employed by a private developer but at the same time had to deal with various government departments as well as a number of consultants from other disciplines. The communication network became more complex. Team members who did not have prior experience on infrastructure projects saw this as a great opportunity to learn. Though some of the members had little experience in infrastructure projects, they found that the knowledge they had gained from other types of projects was also applicable to the current one. Examples include government submission procedures, materials selection, etc. Most of the interviewees said that this project is unique in the sense that infrastructure projects are usually initiated, managed and developed by the government rather than by a private developer. In addition, the number of parties involved in government infrastructure projects is usually very small, unlike this project, which involved so many different parties.

In this project team, some of the team members played a more active role in the project, e.g. the architects and the civil engineering consultants, as they had the biggest input into the project. Other team members, such as the sewage treatment plant consultants and the pier consultants, played a more passive role and only attended meetings when necessary. In addition, they might only interact with those team members that were deemed necessary. Within this project team, there was no clear indication as who was the team leader for the project, as they were all appointed directly by the client and assumed to have equal status. However, the architects and civil engineering consultants assumed a team leader role, as the architects were required to coordinate on the overall design development, whilst the civil engineering consultants had more technical input on the infrastructure project. All team members possess different technical knowledge as well as knowledge in managing the project both internally with their in-house team members and externally with other consultants and the client, and with the would-be contractor. However, the latter knowledge - that of managing projects - varies with individual team members' personal exposure to project management. It usually takes time to build up that knowledge, and they need to learn from experience rather than from textbooks.

CASE STUDY TWO: THE RESIDENTIAL DEVELOPMENT PROJECT

Project Background

The residential development comprises 280,000 square metres Gross Floor Area (GFA), including 8,000 square metres for various commercial uses. The residential towers will accommodate 5,100 units. A ferry pier, which links the island to Hong Kong Island and the adjoining seaside commercial complex along a beach have been planned to create an improved shoreline and waterfront promenade. Two recreational clubhouses, an idyllic landscape of paths, parks, gardens, plazas, sculptures and water features are also provided for the residents of this development. The interplay of architectural and natural elements of the island gives the community cohesion, variety and a distinct identity, which is a must to boost property sales. It is the intention of the developer to create this development as a resort-style residence, partly because of the location and partly to create a distinct image to attract future potential buyers. A similar development nearby has proved to be a successful concept. The development will provide a sense of tranquillity and an innovative living concept, despite the hustle and bustle of the working lifestyle in Hong Kong.

The development will be divided into four phases. The first phase of the development will be completed in late 2002 and early 2003, and the first batch of 800 units, measuring from 400 to 2,000 square feet, was put up for pre-sale in 2001. As environmental concern is one of the core themes of the development, it will be the first town in Hong Kong to be free from the pollution of car fuels. The development will provide a 24-hour shuttle bus service using batteries or liquefied natural gas. High-speed ferries are planned to take the residents to Central. Besides the sea approach, a slip road will be built to link the residence to an existing bridge where residents can take public buses to the nearby railway station.

The design evolution of the residential development is not a linear process; the consultants have been asked to revise the scheme many times to cater for the changing market requirements. Examples include increasing the total gross floor area of the whole residential development, changing the sizes of the flats from large sizes only to a mixture of large, medium and small sized flats, and adding in new recreational features to attract customers.

The Residential Development Project Team

The residential development project team includes the client's project managers, architects, structural and civil engineers, quantity surveyors, E&M engineers, landscape architects, registered structural engineers (registered under the Buildings Department, HKSAR Government for this project), environmental consultants, interior designers (for the toilets and kitchens of typical flats), interior designers (for typical floor lobbies and main lobbies), interior designers (for the central clubhouse) and lands consultants (building plan).

Though all the team members have technical knowledge in their respective disciplines, one type of knowledge that they require is knowledge of the latest market conditions. A lot of consultants do not have this sensitivity to the market, as it demands a lot of attention and time other than their own professional discipline. The client's project managers (PM), in these circumstances, play a very important role in advising on some of the knowledge areas that may be missed out by the consultants. In addition, the client's PM also acts as a conduit between the client's senior management and the consultants in commenting on the consultants' designs and the selection of certain materials or products that will have implications on the development.

ANALYSES AND LESSONS LEARNED

The purpose of these two case studies was to examine the processes by which knowledge is co-constructed during the design development in two different types of projects, namely, infrastructure and residential development. Four lessons that emerge from these two studies are analysed below: (1) the process of information seeking; (2) the process of boundary crossing; (3) the process of project learning; and (4) the process of balancing multiple stakeholders' perspectives.

The Process of Information Seeking

This mechanism refers to the process by which project team members search for information or knowledge when they encounter some issues or problems with which they are not familiar. Rouse and Rouse (1984) define information seeking as:

> "The process of identifying and choosing among alternative information sources."

They further elaborated that

> "The process of information seeking is dynamic in that the methods and criteria whereby information is elected or rejected often vary in time and depend on intermediate results … The environment within which information is sought is also typically dynamic in the sense that information changes in time as does its usefulness."

Dervin (1983) defines information seeking as a process of sense-making in which a person is forming a personal point of view. The individual is actively involved in finding a meaning which fits in with what he or she already knows, which is not necessarily the same answer for all, but sense-making within a personal frame of reference.

Among all the interviews conducted, almost all project team members suggested that they will look at their own experience first to see whether they can deal with the issues at hand, follow by consulting others' experiences which can be both colleagues or persons in their own personal network. From their experience, those that they approached, if they had related experience, were usually willing to help even though they might be working for a rival firm. They have a mutual understanding that they will not ask for sensitive information like the fee their company bid for the project, etc. That is, they will not ask for information that might put the rival company at a disadvantage. The last resource they will approach is published sources. Usually this requires an ample amount of time to conduct the search, and sometimes others' experiences can lead to pinpointing a particular publication or person to contact for further information. It seems that the construction industry is working pretty well on this and people are willing to share knowledge, as there is an unspoken culture that next time, you may need others' input as well.

Attributes accounting for the prevalence of informal oral communications among team members in the two case study projects include the nature of the team members' work tasks. They dealt almost entirely with practical knowledge and practical knowhow, which are not usually transmitted through documents. One other reason why informal oral channels were favoured by team members is that this kind of communication is user-directed and this makes it very popular with practitioners, whose main interest is to get on with the job at hand without unnecessary waste of time. The prevalence of informal oral communications can also be accounted for by the fact that interpersonal channels typically carry auxiliary information and, in effect, complement the operation of the more formal ones.

Allen (1977) concludes that

> "Engineers' information seeking and communication behavior is reminiscent of Zipf's (1949) Law of Least Effort. According to Zipf's law, when individuals must choose among several paths to

> a goal, they will base their decision upon the single criterion of least average rate of probable work. In other words, to minimise his average rate of work expenditure over time, an individual estimates the probable eventualities, and then selects a path of least average rate of work through these."

Informal oral channels of communication were not without inherent problems despite the fact that they were much more favoured by team members over written channels. One of the major problems associated with oral channels was that it was sometimes difficult to identify which individual had the right kind of information that was required. From the interviews with the project team members, there seems to be an intuitive way of relating people from a department in their company or in a particular field to solve a problem.

Written channels were the second most favoured means of information seeking and communication by project team members. They preferred the use of literature for seeking certain specific pieces of information. For example, information on standards and specifications was sought from the literature.

McLaughlin et al. (1965) made the following observations with regard to circumstances under which one may choose oral or written channels of communication:

> "If you do not know something, the first impulse may indeed be to 'ask somebody', but if you need to be sure of the information, or need a precise answer, or don't need a long study, the impulse may be to look it up."

The Process of Boundary Crossing

All project team members do project work that spans outside their core into multiple disciplines. Crossing into an outside domain requires boundary work (Fisher, 1990). There are three interconnected types of boundary: those created by the dispersion of organisations, the reality of different organisational cultures, and the existence of functionally specific knowledge. Table 1 lists structures where the team members do boundary work. So far, project team members perform boundary work in various offices; other frameworks for boundary work include collaborations, personal networks and meetings. As the team members perform this work, certain objects can assist with their attempts to cross boundaries. According to Star and Griesemer (1989), boundary objects help people to cross borders and come together to solve a problem by inhibiting "several intersecting social worlds" and satisfying "the informational requirements of each" (p.393).

Frequently, concrete things are a pivotal feature of discipline crossing. Drawings, reports, correspondences and specifications are shared between different professions and sometimes brought together for discussion or input from other disciplines. Methods move across boundaries in a number of ways. Team members may bring a number of techniques and procedures from a variety of different disciplines to their design problem.

Words can also be the meeting point for different disciplines. Metaphors can act as models, creating new frameworks for design phenomena. A number of team members talked about using metaphors as a tool to help groups of people from disparate backgrounds think about a problem in the same way. Words and concepts cross discipline borders and, over time, the vocabularies of different communities change and merge. As certain terms become more broadly applicable, there is more cross-communication between disciplines.

Boundary work is the cooperative pursuit of tasks in spite of boundaries that could prevent separate social worlds from achieving goals (Gieryn, 1995). Boundary objects may not be critical in highly interactive situations. The project team accomplishes important boundary crossing through conversations among team members.

The Process of Project Learning

A large part of learning takes place “in context” in design and construction, that is, on the project. This is true of apprenticeships in crafts and of supervisors who move up from the trades. But it is also true of those who are formally educated in various disciplines who must learn the realities of their job from experience. Even consultants whose work is less affected by the complexities and unpredictability of the construction site place a high premium on site experience, as this is the place where they can test out their design. It is unfortunate, as described by a few team members, that when the construction of a project is completed or nearly completed, they will be assigned to another project by their companies and have very little chance of seeing whether the design and details they prepared on drawings are workable or not. They do know that very often, the tradesmen on site have modified the details on site to make the design work. Unless this practical or site knowledge can be channelled back to the consultants, they have no way to find out whether a design they have drawn is working or not. Talking to the people who carried out the work on site can enhance one’s practical experience, as the design itself needs to consider the process of making a product. This was the case with the geotechnical engineers interviewed, who frequently went to the site to learn the practical knowledge of drilling holes for the submarine pipelines.

Both residential and infrastructure developments require complex multi-disciplinary work. This can be seen from the number of consultants involved on the project or the number of team members participating. The project teams are quite free to accomplish their professional work and project goals. To achieve this, multi-disciplinary teams of professionals are required who can self-organize to meet unpredictable problems and knowledge needs as they engage in the design processes. From the very first, the client's project managers have designed an informal work environment which allows and encourages individual professionals to pursue working relationships as their work demands. This environment allows individuals, as well as groups, to organize their working and learning relationships as the situation demands. This creates a complex work and learning environment in which both the individual and the group develop their skills and abilities. Much of the literature in adult learning and professional development in the workplace focuses on how the individual learns a set of established skills and knowledge. There are a growing number of studies that examine learning and transformation in a shared group experience (Taylor, 1997) as well as discovery learning and knowledge generation by teams (Nonaka and Takeuchi, 1995; Davenport and Prusak, 1998).

Individual learning consists of either self-directed activities or collaborative activities where individuals help each other with specific learning activities. In either case, individuals share their learning experience. Learning groups, that is, groups engaged in developing the total sum of their expertise and work methods that can be actualised in new and innovative ways, also have individual members engaged in sharing learning and knowledge. It became clear from observing the project teams in action that learning by individuals and learning by teams are interrelated and need to be understood together as a system.

The observations of the two project teams affirm the literature on teams that effective product development teams produce effective group work and learning when they can freely communicate and interact with many other groups, both within and outside their immediate group. It has been shown that high performing project teams interact more frequently with outsiders than low performing teams (Guest, 1986; Katzenbach and Smith, 1993). To understand these dynamics, one must examine and understand these interactions or "boundary activities" (Ancona and Caldwell, 1990). The project team members have extensive links with other groups and individuals throughout the organization and with the other consultants and personal network. The project team has great discretion in the extent to which it can develop communication links and relationships with other individuals and groups. Individuals within the project teams develop these relationships in many different ways, but because the project team members have a common identity and set of values, they find ways to align themselves to share and reflect on the information and knowledge each acquires. Members develop their own networks of communications and thus the group creates a complex network of relationships. Even when individual group members' networks disagree or are in conflict, the complexity of the total group network creates a more critical analysis of the issues under examination. Group disparity and diversity creates a large variety of external networks among group members, which can provide results that are more effective or productive than the individual (Ancona and Caldwell, 1990). The observations of the project teams confirm this.

Construction project teams need to be multidisciplinary in order to be able to deal with the complexity of broad design problems. The differences in educational background and terminology create a symmetry of ignorance (Rittel, 1984) among the team members. Each team member knows only a part of the problem and is ignorant of the other parts. In order to frame and solve such design problems, members have to mutually learn from each other (Ostwald, 1995). The distinction between teachers and learners is blurred. Every team member has to be able to play both roles.

The Process of Balancing Multiple Stakeholders' Perspectives

A project is any series of activities and tasks for which a certain outcome is expected, within a certain expenditure of resources, to be completed within a certain amount of time (Kraus and Cressman, 1992). In simple terms, the project can be described as a transformation process, superimposed on the regular or cycled activities of an organisation (Beale and Freeman, 1991, p.24). In this regard, a project becomes part of a wider venture (Beale and Freeman, 1991), the first part of which is the production of a product or service followed by an operating cycle. The project therefore takes place within a complex corporate, legal, financial and regulatory environment (Fox, 1984). This environment leads to a number of parties having a stake in the project, from internal departments to external regulatory bodies and customers, since the project decisions have a potential impact on all stakeholders (Cleland, 1986).

It is more than likely that the value criteria of the different customer groupings will conflict with one another, and compromise and prioritising must occur in order to add value in the optimal way. This may mean that the customer groups themselves will be prioritised, forming a hierarchy of customers of increasing importance to the business; or it may be a case of assessing all the value criteria of the customer groups and choosing those that will satisfy the majority of customers.

It could be argued therefore that the organisation must take on a philosophy of value, that is to base all actions and decisions upon the customers' value criteria. It becomes a combination of managing value throughout organisational processes and more importantly defining what value actually means to the customer. Due to the complexity of the customer hierarchy, the design processes and the linkages throughout the value system, it is important that each team member within the project takes responsibility for adding value to their own part of the process whilst ensuring that it adds to the benefit of the whole. For the residential development project, it can easily be thought that only architects can add value to the customers. In fact, this thinking is totally wrong. The structural engineers on the project can add value to the project by using smaller beam and column sizes so that usable space inside a unit can increase, as well as having high ceilings, which most of the customers will enjoy. In the case of the mechanical and electrical engineers, they can choose an air-conditioning system that will require minimum maintenance, has a low noise level and is energy efficient. After all, no customers will enjoy an air-conditioning system that demands a lot of attention, is noisy and consumes a huge amount of electricity. Of course, it may be easy to design something as above purely from the end-users' point of view; however, if the client's or other stakeholders' considerations are added to the equation, the value criteria become much more complicated. For example, a highly efficient air-conditioning system is good for the end-users, but will cost the client more in development costs. This is the intricate part: all the project team members need to strike a balance among the value criteria of all customers.

For the infrastructure project, perhaps one may argue that there are no customers who will buy the infrastructure project as in the case of the residential development. However, the value criteria of the customers, in this case perhaps more appropriately addressed as stakeholders, need to be considered. The first one is the government authorities who will take over the infrastructure and carry out the maintenance in the future. From their point of view, the value criterion of the infrastructure system is low maintenance. Users of infrastructure like a road system value a safe design that can give them full enjoyment as road users. Again, this illustrates that the decision to satisfy the value criteria resembles a seesaw: when one side is down, the other is up. Should we satisfy the value of one customer group at the expense of the others? In these two case projects, through the past experience of all the project team members working on the client's past project or through the knowledge about this client, they have used their professional knowledge and experience to try to strike the best balance among all the stakeholders and to uphold the reputation of this client's products.

CONCLUSION

Construction projects always use a team approach to design, develop and manage, as they require knowledge input from many diverse professional disciplines. This analysis has concentrated on the mechanisms of knowledge creation in two construction project teams, in the hope of understanding and preserving valuable lessons from this team effort. Specifically, it illustrates that the design effort of these two projects was not simply a technical issue but also posed a social and emotional agenda. The analysis highlights a number of important lessons that can be usefully applied to other construction projects.

In particular, four lessons are articulated by this study that can serve as guidelines for construction professionals and clients to ensure the future success of knowledge creation within a multidisciplinary inter-organisational project team. First of all, in the process of information seeking, it is important to understand the working patterns of various construction professionals within construction during problem-solving. Because of the practical nature of the construction industry, experience has been valued highly as a kind of tacit knowledge, followed by the experiences of others; information sources are usually treated as the lowest priorities due to the time pressure from projects. Secondly, in the process of professional boundary crossing, the knowledge required for a construction project requires contributions from various disciplines; thus, they contribute knowledge to their own discipline as well as to other disciplines. The knowledge from various disciplines will be blended together in order to create the required knowledge for the current work. Project team members should learn how to cross the boundaries of organizations, cultures as well as functional through multidisciplinary teamwork. Thirdly, in the process of project learning, owing to the project-based nature of the industry, professionals do not learn among their own professional discipline, rather they learn with other professionals in a project situation. Learning happens when team members encounter something new or even a similar situation is encountered, and existing knowledge or experiences need to be reflected upon to see their applicability in the current situation. Learning can occur in the knowledge domain of one's own discipline as well as in others, as this learning process facilitates the co-construction of knowledge during the design process, so that other perspectives can be taken into consideration. Last, but not least, in the process of balancing multiple stakeholders' perspectives, each project comprises many stakeholders who have a genuine interest in the project, as well as those who may be affected by the decisions. For a successful project, various stakeholders' considerations need to be taken into account. Of course, it will be hard to fulfil every stakeholder's wish list; the project team should use its best knowledge and skills to try to strike a balance among all the conflicting objectives and values. After all, it should be a project that has the best balance rather than pleasing one party at the expense of others.

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Linear Methods for Subcontractor Planning

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ABSTRACT

Building construction has raised in complexity and sophistication in the last few years. Therefore, increasing specialisation is required so that project objectives may be attained. The present tendency for sub-contracting will probably continue, requiring effective management techniques. Sub-contractor planning is a topic of great importance for principal contractors and management teams. Traditional planning techniques dealing with resource productivity do not assure work continuity on site. This may be partially overcome if own resources are to be used but it may be a problem for sub-contractor planning. Actually, sub-contractor work continuity must be assured for current work conditions otherwise the principal contractor may expect productivity lost, claims and delays. Although currently used, CPM based techniques do not assure team work continuity and so additional effort must be made to convert outputs in manageable planning documents. Additionally, if several projects are to be planned for this purpose, the problem raises in complexity and alternative approaches are required. This paper discusses the role of linear planning methods for planning work continuity of construction teams. This includes sub-contractors and other specialised teams operating in the building construction environment. This methods have been first developed for repetitive construction, where work continuity of the same team is achieved in successive similar items in different locations. They may also be effective in dealing with work continuity of distinct inter-related work teams - namely, sub-contractors - in several work locations - namely different successive construction sites - of the same principal contractor.

INTRODUCTION

In the last few years, building construction has greatly increased in complexity leading to the progressive specialisation of construction companies and to the extensive development of subcontracting. This shift in construction production

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system is quite evident nowadays and has been extensively mentioned in several parties, but the study of its effects has not deserved enough consideration in the literature so far. However, this tendency to subcontracting will probably continue in the near future thus suggesting more research on this topic aiming at the development of adequate management tools to deal with subcontractors. Several references can be found on subcontracting selection and their influence in productivity [Ali A. Shash, 1998] [1][2], but specific planning techniques are hard to find. Yet, time planning is an important current topic in construction for which subcontractor planning presently plays an increasing role. This paper reports author ongoing research on this topic at Civil Engineering Department of the University of Minho in Portugal.

SUBCONTRACTING IN PORTUGUESE CONSTRUCTION INDUSTRY.

The importance of subcontracting in building construction in Portugal nowadays, mainly follows from general contractors present strategy that reflects market conditions and specific conditions of this economic sector. Several studies point out the variability of demand as the main reason because it makes difficult to keep a board of permanent workers in larger companies. These companies are also less flexible to market fluctuations and less adaptive to different work natures. Therefore, for those companies, subcontracting is a way of surviving to market variation and a way of managing the uncertainty of getting future projects. Moreover, subcontracting decreases operational costs because costs of sub-utilisation of labour and plant can be greatly controlled. Actually, the project portfolio of such companies would not possibly allow for work continuity for specialised teams if they were dimensioned for peak situations [Brandli, 1998] [3][4]. However, for general contractors wishing to keep high performance levels in their projects, the use of subcontractors encompasses careful selection, regular assessment and the achievement of reciprocal confidence, this not being an easy job in view of present subcontractor patterns and concurrence in Portuguese construction activity.

The review to the literature evidenced some recent studies on subcontractor selection procedures adopted by international general contractors and factors affecting subcontractor selection for a specific project [Kumaraswamy 2000] [5]. According to a study conducted in Colorado, USA, among the latter factors are the prestige of the general contractor, its capacity to adequately plan and manage the project, the accomplishment of payments to the subcontractor in due date and the relationship between them in former projects [Ali A. Shash. 1998] [1][2]. Main factors affecting subcontractor quotation at general contractors are professional relations, work capacity and the perspective of future business. More recently [Elazouni, 2000] [6] a *Decision Support System* has been presented in order to help general contractors to decide upon which work portions they should subcontract. The system includes a linear programming model the objective function of which minimises total project costs, and a set of restrictions expressing the objectives of the general contractor, resource limitations and others that may be imposed by the client or site management. The system allows to find works that can advantageously be subcontracted, perform economic and sensitive analysis by trying distinct work scenarios and so on. The influence of subcontracting in construction productivity has also been object of research in Taiwan [Ting-Ya Hsich, 1998] [7], that evidenced increasing importance of subcontracting and the lack of consideration of its effects in productivity studies and in the accomplishment of project time objectives.

MANAGING SUBCONTRACTORS WITH LINEAR SCHEDULING METHODS

Background

Current programming methods do not generally assure building work team continuity. The problem is partially overcome for general contractor work teams if workers can be re-arranged in other teams and moved across simultaneous projects, but not if they are subcontracted. However, general contractors usually care for subcontractor work continuity because this tends to ease procurement, increase production and prevent undesired delays in their projects. Moreover, general contractors may also find productivity improvement if work continuity is assured for their own building teams, instead of changing team constitution.

Therefore, general contractors may advantageously manage subcontracted teams if their work may be continuous, despite some possible lack of productivity. Usual construction scheduling methods (like bar-charts and critical path) are efficient in activity sequencing but do not take work continuity into consideration. Besides, they are mostly directed to single projects not to a set of projects taking place at the same time, although this is essential for the above objective. Sometimes, resource distribution may be improved by changing production rates according to activity float but work continuity among simultaneous projects is difficult to achieve this way.

Programming methods for repetitive construction like the *Linear Scheduling Method - LSM* achieve work continuity for resources required to perform project activities taking place at a constant rate. LSM was first presented by Chrazanowsk in 1986, shaping identically to *Line of Balance* diagrams method, in which project activities are plotted as ascendant lines sloping upwards in an orthogonal system in which horizontal axis is a time scale and the number of units produced is represented in the vertical axis. The slope of each line means the production rate of the work teams allocated to the activity represented by that line. The project evolution in a given time instance can be easily analysed by drawing a vertical line in that position in the time scale and reading its interception in activity lines [Chrzanowsk, 1986] [8]. The advantages of this method when compared to traditional scheduling methods are as follows:

Simplicity of diagrams.

Decrease in scheduling time and effort.

Easy perception of the project logic.

Ease of monitoring.

Resource use continuity.

It also has some disadvantages as:

Need for strict project control.

Some activity float and supplementary resources must be allocated to the project in order to overcome unpredicted resource shortage that may risk established programme.

Difficult to use with computers.

It may be concluded that LSM is more adequate to manage repetitive construction projects than traditional scheduling methods but must be used carefully [9][10]. In view of the problem to be solved and the impracticability of traditional scheduling methods to handle it, it was decided to test the use of LSM for that purpose.

Case Study

The problem is programming a set of construction teams of several specialities working for a general contractor (either subcontracted or not), in a set of projects taking place at the same time. It is assumed that each project has been previously scheduled by any method and that teams to manage are involved in activities identified in each project. The aim is to get the best possible solution for work continuity of teams involved, minimising changes to the programme established for each project. LSM will be used to schedule those activities, keeping the number of teams required as low as possible.

In this case study, a general contractor has four repetitive projects under way, the programme of which are not presented, each comprising three subcontracted activities **a**, **b** and **c** that should be scheduled, so that team work continuity among projects may be achieved. Besides, activities **a**, **b** e **c** are sequential in each project, with end-start precedence relationships among them, for a matter of simplicity. It is assumed that each **a, b** or **c** may be executed by a single type of specialist subcontractor also named **a, b** or **c** type, respectively.

This is plotted in the diagram of figure 1, with the number of units constructed in each project represented in the vertical axis and a time scale in the horizontal axis. The vertical axis is therefore divided into four sections, one for each project. Line segments $\mathbf{a_i}$, $\mathbf{b_i}$ and $\mathbf{c_i}$ represent activities **a**, **b** and **c** of project **i**, taking place at constant rates, as follows from the programme of project **i**. Generally speaking, activities of figure 1 have positive total floats, except for those pertaining to the critical path of their corresponding projects, in which case they have zero float (like activities $\mathbf{a_2}$ and $\mathbf{a_3}$). Therefore, activities can take place at any time in the shadowed area that is a parallelogram with early start and finish dates as well as latest start and finish dates in its angles. For critical activities, early and late dates coincide, therefore they are represented with no shaded area, of course.

Figure 1 also represents disconnections among activities of the same type in distinct projects. Disconnetctions are generally inconvenient because they bring work discontinuity for teams subcontracted or the increase of their number. In figure 1 $\mathbf{K_{i,j}}$ is the disconnection between activity **K** of projects **i** and **j** and may be positive, thus implying inactivity, or negative, meaning simultaneous work needed for subcontractors of type **k**. Both cases should preferably be avoided in the sense that work continuity is intended for subcontractors along with the minimisation of their number.

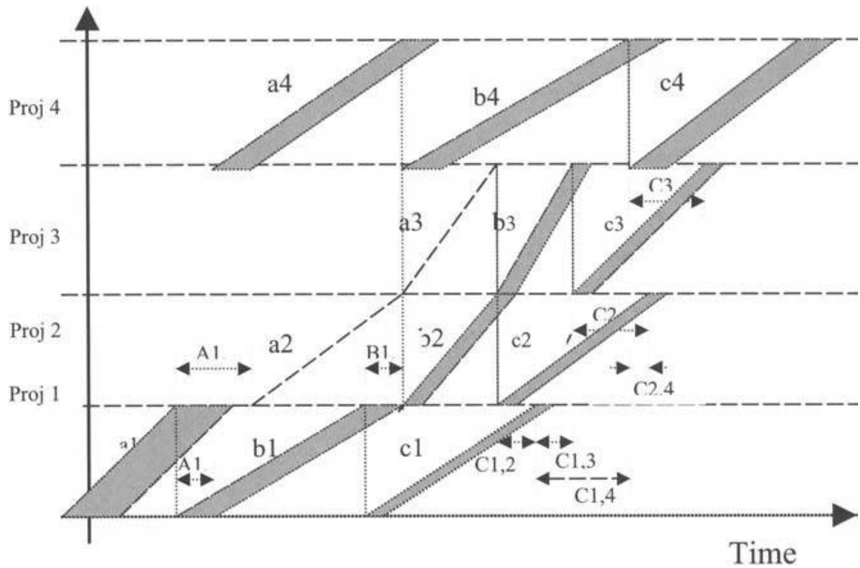

Figure 1 Case study for three subcontracts and four projects.

Figure 2 shows a solution for the problem as follows:

- Using the float of activity $\mathbf{a_1}$, work continuity between project **1** and project **4** is achieved, that is, the subcontractor of type **a** that will make project **1** continues to project **4**, and this allows to erase $\mathbf{A_{1,4}}$. Execution of activities $\mathbf{a_2}$ and $\mathbf{a_3}$ calls for a second subcontractor of type **a** but work continuity is assured between projects **2** and **3**.

- Activity $\mathbf{b_1}$ cannot start on its early start date because of the late start of $\mathbf{a_1}$, but the subcontractor of type **b** that will make $\mathbf{b_1}$ may achieve work continuity through projects **2** and **3** in activities $\mathbf{b_2}$ and $\mathbf{b_3}$. However, a second subcontractor of type **b** is also needed because activity $\mathbf{b_4}$ takes place at the same time of activities $\mathbf{b_2}$ and $\mathbf{b_3}$. It may be contracted for project **4** alone, or work continuity between activities $\mathbf{b_1}$ and $\mathbf{b_4}$ may be tried although assuming disconnection $\mathbf{B_{1,4}}$; in this case, the first subcontractor of type **b** will just handle projects **2** and **3**. This is the solution depicted in figure 2.

- For activities $\mathbf{c_i}$, the option has been two subcontractors: The first will make activities $\mathbf{c_1}$ and $\mathbf{c_3}$ and the second will make activities $\mathbf{c_2}$ and $\mathbf{c_4}$. Disconnection $\mathbf{C_{1,3}}$ being important, a temporary increase of work teams in project **2** may be envisaged, leading to an increase in the production rate of $\mathbf{c_2}$ during that period of time. After the conclusion of $\mathbf{c_3}$, the reinforcement of work teams of $\mathbf{c_4}$ is suggested, leading to an increase in the production rate of this activity. These options are depicted in figure 2.

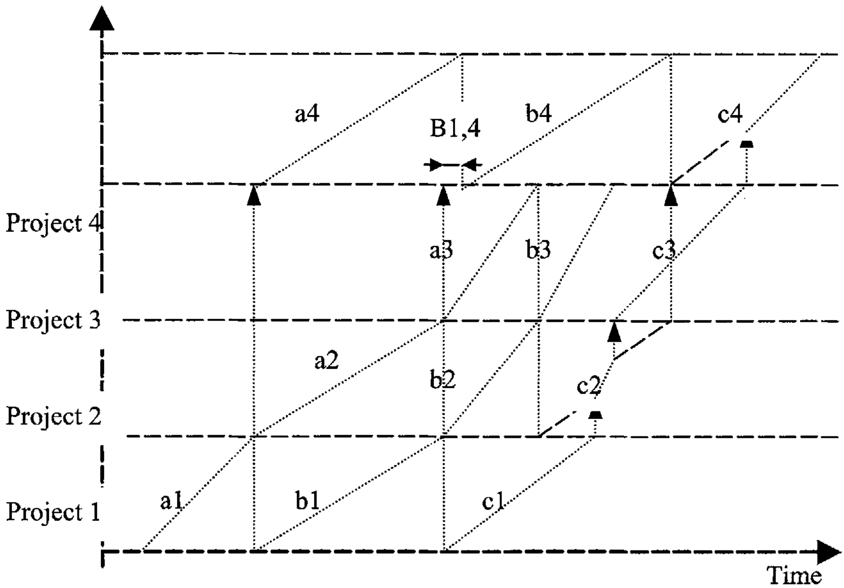

Figure 2 Solution of the case study achieving work continuity for subcontractors.

It is relevant to note that activities $\mathbf{c_2}$ and $\mathbf{c_4}$ do not keep a constant production rate but this does not bring any difficulty in handling the problem.

CONCLUSIONS

Subcontract scheduling in construction should preferably consider two types of precedence relationships: Those that keep the logic of each project and those that assure work continuity among distinct simultaneous projects in which subcontractors may be involved. This is a problem for which traditional scheduling methods are not suitable and it is similar to scheduling repetitive high raise buildings which encompass both a horizontal logic (that is, for each level) and a vertical logic (that is, between successive floors). The solution for this problem with linear scheduling methods has been extensively suggested in the literature. The case study presented above shows how identical methods may be used for subcontract scheduling. Besides, the method allows for variable production rates for construction activities, thereby contrasting with traditional scheduling methods.

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Consensual Approaches to Siting Controversy

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ABSTRACT

Poor public perception can obstruct a construction project in a damaging way. Knowledge about public opinion should be considered as a relevant area of expertise for project managers and as an essential cost element in the planning and completion of construction projects.

A consensual approach to a siting controversy requires informal face-to-face interaction among chosen representatives from all stake-holding groups. The basis of a consensual approach is to seek all-gain solutions rather than win-lose solutions or political compromise.

Consensual approaches to solve conflicts between project stakeholders should increase the efficiency in the construction process. Conflicts between project stakeholders should be solved in dialogue to seek the best solution for all parties, instead of end up in court where the purpose is to interpret the law, not to reconcile conflicting interests.

This paper will describe a consensual approach to siting controversy, with focus on analysis and management of project stakeholders. The City tunnel project in Malmoe, Sweden, is used to exemplify a stakeholder management process and how their efforts correspond to a consensual approach.

INTRODUCTION

What is a Siting Controversy

A construction project affects different stakeholders in both positive and negative ways. The positive affects can be, better communication, better housing or higher standards of living. The negative side of a construction project is that it can bring deterioration in the physical environment for affected local communities. This could lead to conflicts and controversies about the siting of a construction project.

"Today managing the public image of major civil engineering projects is at least as important as managing their physical creation? Poor public perception can damage or stop a project as surely as can bad ground or shortage of labour and materials. The Channel Tunnel project is a classic example: for much of its formative period it existed in an often destructive climate of adverse public opinion. Most of this was avoidable, but it resulted in the project team spending much of its time fighting a rearguard action rather than simply getting on with the job"(Lemley 1996)

Siting controversies are common in most large and controversial construction projects, as for example, highways, railroads, hazardous waste facilities etc. But even in smaller and seemingly uncontroversial projects controversies about the siting of a project may arise. Siting conflicts reflect two key elements (Edelstein 2001). On one hand the need solve a problem. The disposal of solid wastes is an example. There is a need for adequate, cost-effective and safe methods for disposing solid wastes generated by the society. On the other hand both the facility to be sited and the problem it is suppose to solve are likely to be stigmatised and subjected to anticipatory fears. As a result the facility is thought of, by the affected community, as an act of violence to that community.

If a siting controversy is not resolved the outcome often becomes a costly process of adverse public opinion, bad press and a time consuming juridical process. If project managers instead try to find all-gain solutions, which benefit all parties, the conflict may be resolved. Even if all-gain solutions cannot be found the effort in itself may increase the level of acceptance for the project.

Relationships Between Stakeholders in the Construction Process

In a construction project it is important to identify those stakeholders who can affect the project, and develop tools and techniques within the project to handle demands of different stakeholders. Managing stakeholder demands is not uncomplicated, often because aims and demands of different stakeholders are not uniform and sometimes in direct opposition to each other. In siting controversies are opposing interests between project management and external stakeholders almost always the basis of the conflict. Here the outcome of a stakeholder management process is largely due to the personalities of involved parties and not a deliberate strategy by the project management. Methods of communication between project stakeholders are therefore needed to reduce the risk of not resolving a siting controversy.

The relationship between project management and external stakeholders can be described as a triangle of power (Fog et al. 1989). The power triangle consists of three stakeholder groups (figure 1).

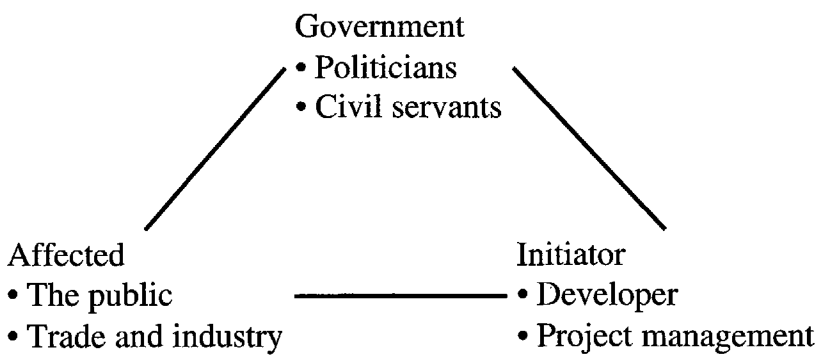

Figure 1 Relationships between different stakeholders - power triangle (Fog et al 1989)

Each stakeholder affects project processes with its special form of power, political, economical or juridical. Interests of stakeholders, in the power triangle, are both of a co-operative and a counteractive nature, between and within different stakeholder groups. Since the developer has the largest interest to implement and complete the project, they also have the largest interest to resolve conflicts that may arise. Communication management and conflict management should therefore be considered as important tasks for a developers project management team.

THE CONSENSUS BUILDING APPROACH

Conventional methods of dealing with disagreements, particularly in the public sector, are increasingly inadequate. At every level of government, officials have discovered that the "decide-announce-defend" model of the past is unacceptable. Many are looking for new ways to generate informed agreements or to resolve disputes when they arise. (Consensus Building Institute, USA)

The concept of consensus building is developed for solving conflicts in various types of projects. Consensus building requires informal face-to-face interaction among chosen representatives from all stakeholder groups. The methods basis is an effort to seek all-gain solutions rather than win-lose solutions or political compromise.

The background to consensus building is the fact that attempts to build prisons, highways, power plants, mental health facilities, or housing for low-income families often are obstructed by nearby residents. Another reason was that public policy disputes often end up in court. Unfortunately the courts are often unwilling to fashion remedies that meets the needs of all sides. Simply put the courts purpose is to interpret the law, not to reconcile conflicting interests, which makes all-gain solutions impossible. (Susskind, Cruikshank 1987)

The mutual-gains approach of consensus building involves an interaction between project stakeholders. In that context project management should (Susskind, Field 1996):

- Acknowledge the concerns of all sides
- Encourage joint fact finding
- Offer contingent commitments to minimise impacts if they do occur, and promise to compensate knowable but unintended effects
- Accept responsibility, admit mistakes and share power
- Act in a trustworthy fashion at all times
- Focus on building long term relationships

Managing a project with the aid of consensus building makes the project stakeholders aware about the possibilities to reach an agreement and the amount of co-operation that is necessary to achieve the agreement. To achieve consensus comprises a number of steps (Davy 1997):

1. To identify all stakeholders whose interest are involved in the siting of a construction project:
2. To explore the scope and nature of their initial disagreement or agreement:
3. To invent options for mutual gain and for "packaging" (trading of negotiable items that are valued differently by different stakeholders):
4. And, if an agreement can be reached, to commit the stakeholders to their agreement and to arrange for its implementation and monitoring.

The first and maybe most important step to reach consensus are stakeholder identification and the analysis to explore initial agreements and disagreements. This involves a process of stakeholder analysis and stakeholder management.

STAKEHOLDER ANALYSIS AND MANAGEMENT

To reach a consensual solution to a problem the project manager must first and foremost acknowledge the concerns of different stakeholders. To achieve this, stakeholders and their impacts to the project must be identified.

Project stakeholders are individuals and organisations who are actively involved in the project, or whose interest may be, positively or negatively, affected as a result of project execution or successful project completion. The project management team must identify the stakeholders, determine what their needs are, and then manage and influence those expectations to ensure a successful project. (PMI 1996)

Identification of Stakeholders

Every project has a set of key stakeholders, (PMI 1996):

- Project management - the individual or individuals responsible for managing the project
- Customer - the individual or organisation that will use the project product.
- Performing organisations - the enterprises whose employees are most directly involved in doing the work of the project.
- Sponsor or owner - the individual or group within the performing organisation who provides the financial resources for the project.

The relationship between key stakeholders are often described within the formal organisation, but when identifying stakeholders it is not enough to focus on formal structures of project organisation. It is also necessary to have a look at informal and indirect relationships between stakeholder groups and to assess their importance (Johnson, Scholes 1999). In addition to the key stakeholders there may be many different individuals or groups that should be considered as stakcholders for the project.

Stakeholder Mapping

To effectively manage stakeholder interests it is not enough to just identify their impact. Project management must also identify the power different stakeholders has on the implementation of the project. A method to do this is stakeholder mapping (Johnson, Scholes 1999), this approach is adapted from the concept of environmental scanning (Mendelow 1981). A tool in stakeholder mapping is the power / interest matrix (figure 3) that analysis the following questions:

- How interested is each stakeholder group to impress its expectations on the projects decisions?
- Do they mean to do so? Do they have the power to do so?

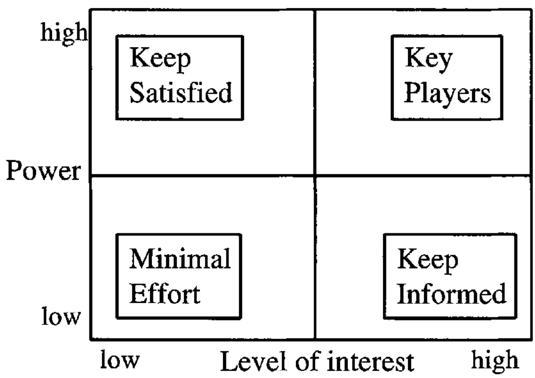

Figure 3 Stakeholder mapping, the power / interest matrix (Johnson, Scholes 1999)

The fields in the matrix are defined as follows:

Key Players: The most important stakeholders with high interests in the project and high power to influence project implementation and completion. These stakeholders must be involved in all relevant project developments.

Keep informed: Stakeholders with a high interest in the project, for instance nearby residents to a construction project, but with limited means to influence the project. Despite of their low power these stakeholders could be powerful enemies or allies when influencing attitudes of more powerful stakeholder groups. Their interest in the project must be taken seriously through dialogue and information.

Keep Satisfied: These stakeholders are often passive, but can exert a great impact on the project. Stakeholders in this group can often be found in institutional investors and legislative bodies. The relationship between a relative low interest and a high level of power makes these stakeholders difficult to handle, it is therefore necessary to analyse their intentions and to involve them according to their interest.

Minimal Effort: These groups do not have a high interest nor do they have the power to exert impact. These groups should be informed only to a necessary extent, and not much effort should be invested into them.

By grouping stakeholders in the power / interest matrix, project management may achieve a better picture on how communication and relationships between stakeholders should be developed to reach consensus about and acceptance for the project and its implementation

Communication Between Stakeholders

Communication is an essential part of project management efforts to reach consensus. Today communication related processes are maybe more important than ever, because of the media's impact on the information flow. Project management should in many cases more openly communicate both good and bad aspects of the project to ensure a correct information flow in the media and to avoid bad press.

Communication related processes aim to facilitate the exchange of information necessary for the project. They ensure timely and appropriate generation, collection, dissemination, and storage and ultimate disposition of project information. Communication related processes are as follows (SS-ISO 10006):

- Communication planning: planning the information and communication systems of the project.
- Information management: making necessary information available to project organisation members and other relevant stakeholders.
- Communication control: controlling communication in accordance with the planned communication system.

If the project management, through communication can create a good dialogue, it may be easier to find the real conflicts about a project and eliminate false conflicts and misunderstandings and thus reach consensus and acceptance

(De Laval 1999).

CASE OF THE CITY TUNNEL PROJECT IN MALMOE, SWEDEN

The main purpose of the City Tunnel project is to improve public transportation in the Oresund region (western Denmark and the south of Sweden, with the main cities Copenhagen and Malmoe) together with the Oresund Bridge, and relieve other railway tracks that today are overloaded.

The City Tunnel consists of 18 km of railway tracks, where 6 km of the line passes trough a twin tunnel beneath the centre of Malmoe. Construction is expected to begin in 2003 and to be completed in 2008. To this day the final approval of the project is not decided, which makes stakeholder management and communication all the more important.

Figure 4 Project goals and criteria for success (The City Tunnel project annual report 2000)

Stakeholder analysis

The stakeholder analysis made by the City Tunnel project combined with the main project goals (time, quality, economy and environment) has defined five criteria for success in the project (figure 4). The two

most important criteria in order to reach consensus and acceptance with affected stakeholders are an open and credible attitude, in this sense information about the project, both good and bad, are announced correctly and openly (City Tunnel Consortium 2000). The main principle is that a decision shall not be made if it cannot meet the five criteria. For instance if a decision, for some reason, cannot be made public it should not be taken.

The stakeholder analysis (as seen in figure 4) has identified six major stakeholder groups that may have an impact on the project. I have placed these stakeholder groups in the power / interest matrix in order to get a view on their potential impact on the project (figure 5).

The Ownership of the City Tunnel project consisted from the start in 1997 of 4 organisations (the National Rail Administration, Swedish State Railways, the City of Malmoe and Region Scania, Sweden). In the summer of 2001 the project was reorganised so that the National Rail Administration become the sole owner. The other three are still a part of the project as financiers. The project management regard the present and former owners as the key stakeholders in the project. It is their demands that are seen as most relevant.

The Public is regarded as an important stakeholder by the project management, even though they have a limited power to influence the project. Because the City Tunnel project is a large public investment, a public acceptance is relevant to implement and complete the project in a satisfactory way. Since this is a public transportation project the public is regarded as the final customer and user of the completed project, therefore it is important to treat public demands and opinions with respect in an open way. There is also a smaller group of the public whose physical environment is affected by the project. In addition to project strategies of good and credible information and openness about project problems and opportunities, reference groups in specially affected areas have been established. The purpose of reference groups is to create a dialogue with the affected public to solve problems and find solutions to a disagreement.

Businesses and organisations impacts to the project are in many ways similar to the public. Affected organisations may have a large interest in the project, but limited power to influence it.

Employees and suppliers are important stakeholders for every project or company. They have, for obvious reasons, a large interest in the project and some may even have a great impact and influence on it.

The media is an actor and stakeholder that may have very high impact on a project. Even if the media do not have the direct power to influence the project, they have an indirect power to influence decision-makers and public opinion. In a public project as the City Tunnel the opinions of the public and political decision-makers are essential. These opinions are often controlled by the media flow, it is therefore important for the project management to have an open and credible flow of information to the media.

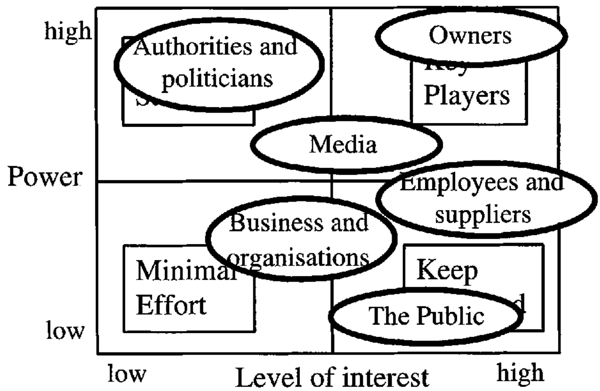

Figure 5 Power / interest matrix for the City Tunnel project

Authorities and politicians are a stakeholder group that may, in general, have a limited interest for the project, but can have a tremendous impact when it comes sanction finance and permits for a project, especially in public investments. The City Tunnel project are at present (autumn 2001) in the middle of a process, where the Swedish parliament are about to decide if the project will continue or not, at this time this makes them a very important stakeholder group with a high level of power about the future of the project.

Consensual approaches for the City Tunnel project

Does the City Tunnel project meat up to the consensus building approach as it is described in this paper? The main strategy for the City Tunnel project when it comes to building consensus is, as I see it, to act in a trustworthy fashion at all times. All their criteria (se figure 4) for success involve the concept of building trust. Another aspect of trust is to accept responsibility, admit mistakes and share power. In this sense the City Tunnel project is open about both good and bad things. As an example the benefits of the project have been questioned, largely depending on project managements release about an estimated increase in project costs. This release has hurt the project on a short-term basis, because of a debate about whether or not the project should be approved to continue, but even if the project will continue or not the long-term result may be an increase in trust for this kind of project organisations. With trust other consensual aspects almost automatically follows.

When it comes to acknowledging the concerns of all sides the City Tunnel project tries to find forums for dialogue through public meetings and an open and credible communication between stakeholders. The reference groups are one effort to try and reach consensus through communication and dialogue. The purposes of the reference groups are also to build a long-term relationship with the affected public throughout the entire project.

CONCLUSIONS

I believe that there are at least two factors that determine if consensus can be achieved. First there must initially be a consensus among project stakeholders that the current situation is unacceptable. Second when the need for a solution is established different alternatives must be investigated objectively, preferably in co-operation with project stakeholders.

Have the City Tunnel project then succeeded in their efforts to build trust and consensus? In one sense they have. The need for the project and the alternatives has been studied. There is a broad consensus about the need to strengthen public transportation in Malmoe, but the alternative solutions are still debated and the final political approvals for the project are still not determined. The public opinion is relatively favourable compared with other projects of this kind. On the other hand one cannot determine if this is an affect of project management, or if it is a result of other factors.

The public opinions about the City Tunnel project are measured through a public opinion poll (TEMO 2001). The result regarding trust for openness and reliability was that 55% percent has a high or medium high level of trust while 37% has a low level of trust and 8% did not answer. Because there are few projects that used public opinion polls in this way it is hard to determine if the level of trust is high. Research studies made about other public investment projects (Boholm et al 2000) indicates though that the trust for City Tunnel project is relatively high.

Even though it is easy to measure opinions from different stakeholders it is hard to determine which factors that affects the acceptance of a project. The real challenge for project management is to find methods to determine which factors and actions that affect consensus building and the level of acceptance for the project. There is in this context a further need to study how different actors affect the construction process, formally and informally, and develop methods to manage different and opposing interests for a project.

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The Contract WLC in the PFI Development Process – A Case Study Approach

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ABSTRACT

The Private Finance Initiative (PFI) was introduced in the UK in 1992. The new procurement method uses profit incentives to encourage the private sector service provider to minimise contract whole life cost (CWLC) by implementing CWLC driven solutions, i.e. solutions expected to result in cost savings in the duration of the PFI contract period. Through competition, CWLC driven solutions are a source of value for money for the public sector client. The implementation of CWLC driven solutions is enabled by the integration of the tasks of design, build, finance, own and operate into one long-term contract. Many experts have predicted that PFI will lead to the implementation of design solutions that emphasise the CWLC. Due to the length of the contracts, it is not possible to measure ex post CWLC performance in PFI projects at this time. Data on actual CWLC performance will not be available for another decade. Hence, this paper proposes a case study approach for an investigation of the PFI development process that determines the expected CWLC of a PFI project. This investigation seeks to establish what departures from conventional design solutions have been implemented with the aim of achieving CWLC savings and what the forces are in the PFI development process that affect the implementation of these solutions. The case study approach includes an examination of project documentation, expert assessments and analysis of self-reports obtained as interviews. A particular aspect to be explored in detail in the case study projects is the heating and ventilation solution. It is anticipated that the findings arising from studying this particular design aspect can be generalised to encompass all building design in PFI projects.

INTRODUCTION

The Private Finance Initiative (PFI) was introduced in the UK in 1992. The PFI is an innovative procurement method involving a private sector entity taking the tasks of design, build, finance, own and operate (DBFOO) in the provision of asset-based public services. The private sector entity is hereafter referred to as the PFI Company. The procurement method is characterised by the relationship of a producer of a service (the PFI Company) and a purchaser of the service (the public sector client).

Only a limited amount of research has been carried out into the practical implementation of the PFI due to its relatively short history. This is especially the case with research that focuses on the activities of the private sector. Therefore, significant gaps in knowledge exist on how the underlying theory of PFI works in practice.

The idea in PFI is to define a minimum quality for a service that a client needs to acquire. This is done with an output-based specification. The client invites the private sector to bid for the service provision. The competition, based on an annual service charge, yields value for money for the client. The service payment is linked to private sector performance in the service provision. If the service provision does not meet the specified quality, the PFI Company will suffer a reduction in the service payment. It must be noted that there is no additional payment for performance above specified service quality.

The mechanism described in the previous paragraph creates strong financial incentives to minimise the contract whole life cost (CWLC) in the PFI development process. Firstly, the PFI Company that offers to provide the service on behalf of the public sector with the lowest annual service charge is likely to be awarded the contract. Secondly, the profit of the PFI Company in the project execution is the difference of the service payment and the CWLC. In effect, once contract terms are agreed with the preferred bidder, the implementation of CWLC driven solutions is an exercise of profit maximisation subject to two exceptions. These are the aspirations to avoid financial penalties for not meeting the specified service quality and to increase net project revenue by commissioning the asset as early as possible as this will commence the service payments by the client.

According to CIC (2000), the integration of design, build, finance, own and operate tasks into one single contract gives improved opportunities to implement CWLC driven solutions. In conventional procurement, these tasks have separate contracts or agreements and the opportunities are thereby limited.

The first PFI projects are only a few years into their operational periods. Therefore, the expected CWLC savings cannot be measured *ex post*. An additional problem arising from the phase of the project is that there is no PFI-specific historical CWLC data, and consequently traditional methods like whole life costing introduced by Flanagan and Norman (1983) cannot be used to quantify the CWLC *ex ante*. Thus, a new type of methodology is needed to assess whether PFI projects can deliver win-win solutions offering both value for money for the client and profit for the PFI Company through implementation of design solutions that emphasise CWLC, and to establish how the PFI development process could be changed to encourage the implementation of these solutions.

RESEARCH PROBLEM

The fundamental objective of the public sector client in PFI projects is to procure projects that are the maximum value for money. The client needs to pass on its objectives to the PFI Company executing the project. If this is done successfully, the private sector firms that participate in PFI projects have two principal objectives. The first objective is to be the winning bidder in the project pursued. The second objective is to make the execution of the project as profitable as possible. As outlined in the previous section, the way to achieve these two objectives in PFI projects is to minimise the CWLC.

In order for the public sector client to pass on its objectives to the private sector effectively, the behaviour of the PFI Company in relation to CWLC in PFI projects needs to be understood. This leads to the definition of a research aim. *The aim of this research is to generate a detailed understanding of how the CWLC is determined in the PFI development process.* The research aim can be broken down into three research objectives. The first objective (1) is to highlight the implemented CWLC driven solutions. The second objective (2) is to establish how the development process in PFI projects is different from the development process in conventional projects. The third objective (3) is to identify the forces in the PFI development process that affected (encouraged or discouraged) the implementation of CWLC driven solutions.

The first objective refers to a key term *CWLC driven solutions* that requires definition. These are the aspects of a design solution that can be attributed to the intent to minimise the CWLC and that would not normally occur in a design solution of the same building if procured using conventional methods.

The research objectives were structured following a simple logic. The first and second objectives are to identify the outputs and inputs of the PFI development process respectively. The third objective is to establish how and why the inputs relate to the outputs.

QUANTITATIVE VS. QUALITATIVE

TTF (2000) and CIC (2000) have identified some sources of the value for money for the public sector client. This research seeks to advance this knowledge. TTF (2000) used a methodology that included a questionnaire survey of public sector PFI project managers' perceptions and an analysis of public sector comparators (PSCs). CIC (2000) used a questionnaire survey targeting both private and public sector participants in PFI projects and case studies.

TTF (2000) and CIC (2000) demonstrated that it is possible to draw hypotheses out of a literature review in PFI research and test them using a quantitative analysis. However, the quantitative methods have a weakness in this particular research domain. The weakness arises from two sources. Firstly, the number of forces in the PFI development process that potentially affect the CWLC that can be drawn out of a literature review is considerable. Secondly, the total number of signed building-based PFI projects is around 200 (OGC, 2000). The weakness is that it is not possible to isolate the effects of individual factors in a total population as small as the total number of projects available to be studied. CIC (2000) highlighted this difficulty in its conclusions.

It is perceived that with the current number of building-based PFI projects, it is not possible significantly to further the knowledge generated by TTF (2000) and CIC (2000) by means of quantitative research. It is believed that qualitative research is required to improve the understanding by identifying the key forces in the PFI development process that affect the implementation of CWLC driven solutions out of a large number of potential candidates. It is also felt that there is an opportunity to generate new knowledge by more rigorous qualitative research than used by CIC (2000) in its case studies. For the reasons discussed in this section, the research will use predominantly qualitative methods.

RESEARCH STRATEGY

According to Yin (1994, 9) the case study strategy has a particular advantage when "...a 'how' or 'why' question is being asked about a contemporary set of events over which the investigator has little or no control." It appears that this distinct advantage can be materialised in this research domain. This research seeks to find out: how the CWLC was determined, i.e. which forces in the PFI development process; and why were particular CWLC driven solutions implemented, i.e. were the forces encouraging or discouraging. In addition, the researcher cannot have control over the CWLC in the PFI development process. Due to the apparent suitability of case study, it will be pursued as the research strategy.

The emphasis and strength of case study research is on understanding, not on generalisation, for which it is often criticised. This research seeks to harness this strength of case study research as it is used to increase understanding of the influences on CWLC in the PFI development process. The other common criticism of case study research relates to the potential lack of rigour and filtering a vast amount of information on each case study. This is acknowledged and is taken into account in the development of the case study design.

CASE STUDY DESIGN

Once case study is chosen as the research strategy, a case study design needs to be developed. According to Yin (1994), the case study design needs to consider research framework, question, potential proposition, unit of analysis, linkage of data and the proposition, and interpretation of findings.

Research Framework

A framework enables research clearly to articulate what it aims to achieve. The framework for this research relating back to the objectives formulated previously is illustrated in Figure 1. The proportion of the framework highlighted in Figure 1 is the area of which detailed understanding is generated and where the research will make a contribution to knowledge.

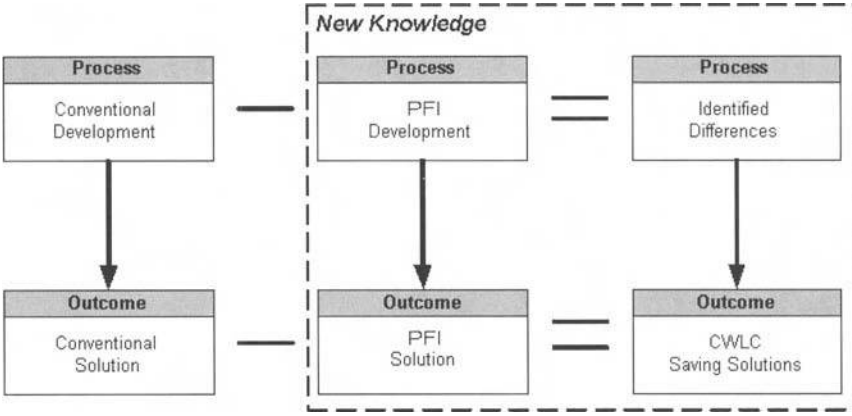

Figure 1 Research framework.

Research Question and Proposition

The nature of this research is explanatory. Therefore, three research questions are formulated and used as propositions. They relate back to the respective research objectives. The desired outcome of this research is to generate hypotheses to be tested in future PFI research. The research questions formulated for the use of this research are:

- What CWLC driven solutions have been implemented in PFI projects?
- How is the development process in PFI projects different (in terms of roles and tasks) from the development process in conventional projects?
- What are the forces in the PFI development process that affected (encouraged or discouraged) the implementation of CWLC driven solutions?

The existing literature gives some idea of the forces that affect the implementation of CWLC driven solutions. Therefore, the third research question is broken down into sub-questions. The sub-questions also serve as propositions of this research, as it is proposed that these forces may have had an effect. The sub-questions are as follows:

- Was the implementation of CWLC driven solutions affected in any way, and if so how, by:
- the constraints on the PFI development process (imposed by the client and Treasury and other governmental guidance),

- the composition of the PFI Company,
- the contractual matters (between private and public sectors and/or within the PFI Company), and/or
- the CWLC decision-making process (information and/or tools available, time, uncertainty)?

Case Study Boundaries

This research focuses on PFI projects that require a new built asset. The facility is used in the service provision for the duration of the PFI contract. The focus is on new build projects because they have more scope to implement CWLC driven solutions than refurbishment projects.

The timeframe of projects to be studied is from the Official Journal of European Communities (OJEC) notice inviting expressions of interest to the commissioning of the facility. As the objectives imply, the focus is on the PFI development process and its effects on the design of the facility. The design and operating regime of a PFI building are determined by the final service that is provided in the facility such as education in a school building. It must be noted that the operating regime used is also influenced by the design. The key reason to focus on the chosen timeframe is that the CWLC is to a large extent determined by the design of the facility, which takes place in that space of time.

The PFI development process and its effects on the implementation of CWLC driven solutions in a project are used as the unit of analysis. Within a project, the study of the effects on the complete design of a building was not seen as feasible. Therefore, the research focuses on CWLC driven solutions in one particular aspect of building design. It is anticipated that the forces in the PFI development process that affect one particular aspect of design will affect all aspects of building design.

The chosen focus is the CWLC driven solutions in heating and ventilation design because:

- The cost of heating and cooling provision will represent a significant proportion of the CWLC.
- The output-based definition of heating and cooling requirements is unambiguous and does not constrain the PFI Company in the selection of a solution from a wide range of alternatives.

- Technological development is likely to present opportunities to implement CWLC driven solutions by innovative design in heating and ventilation.
- Heating and cooling provision is a separate management entity, although influenced by factors outside the specialist designer's control
- Anticipated effects of role integration in PFI on heating and ventilation solutions are substantial as the design takes place in the later stages of design development.

Case Study Selection

CIC (2000) has divided the facility-based PFI market into segments of: accommodation (non-housing), education, healthcare, custodial, housing, transport and utilities. By default, the focus on heating and ventilation excludes transport and utilities from further analysis. This leaves five market segments.

This research focuses on design solutions in office-type and other space. The reason to focus on office-type space is that heating and ventilation in offices is well researched and has relatively simple heating and cooling needs in comparison to other types of spaces. Of the remaining five PFI market segments, custodial and housing are unlikely to contain projects with a significant office-type space component. Therefore, these two segments are excluded from further analysis.

In each case study project, the research will also focus on heating and ventilation solutions in a non-office-type space. A sole focus on office-type space would not give a holistic view of the implementation of CWLC driven solutions. It is anticipated that heavy financial penalties for not meeting the minimum required service output in spaces of critical environmental conditions might affect the implementation of CWLC driven solutions. Office-type space is not seen to be critical, whereas laboratories in universities are an example of this type of space.

To achieve the maximum generalisation of the research results, the case studies will be chosen to represent the three different market segments of accommodation (non-housing), education and healthcare.

The projects chosen as case studies will be 'live projects'. However, the phase that the case study projects needs to be considered. The research focuses on the effects of the PFI development process on the heating and ventilation design. Therefore, the case study projects need to be at least in the latter stages of construction, where the heating and ventilation design is mostly complete, but not necessarily built.

Data Collection

The financial stakes in PFI projects are considerable. Therefore, commercial sensitivity is a major issue in the selection of data collection methods. This led to the decision to use self-report as the main data collection method. Self-reports will be obtained as interviews. According to Carroll and Johnson (1990), they are good in generating understanding of decisions taken. This is especially the case if they are used as one data collection method of a case study. The need to use other methods in combination with self-reports arises from the distortion in the interview data caused by the interviewee. Following the suggestion of Carroll and Johnson (1990), other data collection methods are used in combination with self-reports.

Self-Reports

The main actors in a PFI project are the client and the PFI Company. The client does not normally have a role that enables it to take decisions on the heating and ventilation design. Instead, it guides the design by issuing documentation. Interview data will be collected from the client. However, this data will relate to the project and the PFI development process as a whole, not to the CWLC aspects specifically.

The private sector actors that are most relevant in heating and cooling provision are the architect, the main contractor, building services designer, building services contractor and facilities management (FM) operator. The interview data will be collected from these actors, focusing on the forces in the PFI development process that affected the implementation of CWLC driven solutions. The interview data collection takes into account that some departures from conventional design solutions may also be made, either to avoid financial penalties for not meeting required quality of service provision or to start receiving service payments from the client as early as possible.

Documentation

The documentation in PFI projects can be classified into client and private sector issued documentation. The client issued documentation includes public sector comparator (PSC), output specification, payment mechanism, bid evaluation criteria etc. This documentation has a key role in structuring the PFI development process. It is perceived that this data can be obtained from the client once a working relationship has been established.

The private sector issued documentation includes design and operation briefs, cost estimates, reference design cases, contracts between private sector actors etc. These documents are developed as a response to client issued documents. It is anticipated that commercial sensitivity will be an issue in obtaining private sector issued documentation.

There are categories of data that may be impossible to obtain, especially cost data. The only public sector cost data that may be available is in the PSCs. However, PSCs may not necessarily exist or they may not contain a great level of detail. This has been encountered by, for example, TTF (2000), NAO (1997) and NAO (1998) in their research. The cost data in private sector issued documentation can be seen as a source of competitive advantage. This is due to the non-existence of good WLC data in the public domain. Therefore, it is unlikely that estimates of CWLC performance of PFI projects can be obtained from the private sector.

Consequently, instead of relying on actual or estimated cost information, the research is designed to be independent of this data. Indirect measurement of CWLC performance is used, i.e. CWLC driven solutions are identified. It is perceived that information on the implemented heating and ventilation design solutions can be readily obtained. This is because the design solutions will be exposed to the general public once the building is built.

Expert Assessments

Expert assessments are used to collect information to support the self-reports to achieve the first two objectives. It is perceived that in order to sustain rigour, a data source independent of the case study projects is needed.

The first objective of this research is to highlight the CWLC driven solutions. The case study projects and their heating and ventilation solutions will be described to an acknowledged heating and ventilation expert using design specification language. He or she will be asked to identify how the solution differs from a solution that would have been implemented if the project was procured and designed according to the prevailing practice of non-PFI projects.

The second research objective is to establish how the development process in PFI projects differs from that of conventional projects. The PFI development process in each case study is captured in the self-reports. A representation of the roles and the tasks (content and sequence) in the process is created using simplified versions of recent process representation frameworks such as Aouad *et al.* (1998). An established development expert will be asked to identify the deviation in the process from a hypothetical development process that the project would have followed if it had been procured using conventional methods.

DATA ANALYSIS

The decisions taken to implement CWLC driven solutions are based on individual perceptions or collections of individual perceptions of the PFI development process. Studying individual perceptions will generate understanding of the forces in the process that encourage or discourage the implementation of these solutions. The fact that the research focuses on individual perceptions and the existence of purpose built qualitative data analysis software contributed to the decision to use cognitive mapping as a data analysis technique for the self-reports.

The development of cognitive mapping out of Kelly's (1955) Personal Construct Theory is usually associated with Eden *et al.* (1979) and Eden *et al.* (1983). Cognitive mapping is a technique used to create a model of the personal construct system. This model, a cognitive map, is a representation of a person's understanding of a specific problem. In the context of this research, each cognitive map will be a model of an actor's perception of the PFI development process and its effects on the implementation of CWLC driven solutions.

Cognitive maps capture the values, beliefs and assumptions of an individual in and of the problem domain. The perception of the problem is affected by past experience, expertise gained from other projects, organisational knowledge, human capability etc. These are all represented in the cognitive map of the problem domain (Eden and Ackerman, 1998).

The cognitive maps are constructed from the transcribed self-reports using Decision Explorer (DE), which is the analysis software. The analyses of the maps include a cluster, a domain and a centrality analysis. These are inbuilt analyses of DE and will help to unlock the information in the cognitive maps. This information will describe the key forces in the PFI development process that affected the implementation of CWLC driven solutions in each of the case study projects. It will be used to explain how and why the established differences in the development processes and the implemented CWLC driven solutions relate to each other as perceived by the owners of the cognitive maps.

The self-report analysis will be extended using the information extracted from the project documentation and the expert assessments. The CWLC driven solutions claimed to have been implemented by the various project actors will be confirmed or rejected depending whether they are identified as departures from conventional solutions in the expert assessment. In addition, the presence of key forces in the development process that affected the implementation of CWLC driven solutions as perceived by the project actors will be confirmed or rejected with the information extracted from the project documentation and the expert assessment of the PFI development process.

SUMMARY

This paper develops a case study approach to the CWLC in the PFI development process. The aim of the methodology is to generate detailed understanding of how the CWLC is determined in the PFI development process. This is done to enable the production of information that facilitates the public sector client to align the objectives of the PFI Company in PFI projects with its own objectives more effectively.

Due to the limited amount of research in the problem domain and the large number of forces in the PFI development process potentially affecting the implementation of CWLC driven solutions, the developed case study approach will use predominantly qualitative data collection and analysis methods. The case studies will focus in particular on the effects of the PFI development process on the heating and ventilation solution. It is anticipated that the forces that affect this particular design aspect will affect all aspects of building design in PFI projects.

The main type of data to be used in the case study analysis is self-reports obtained as interviews. This data will be analysed using cognitive mapping aided by Decision Explorer software. The analysis will be further extended using information extracted from public sector issued project documentation and expert assessments. The complete analysis will identify the implemented CWLC driven solutions and the forces in the PFI devolvement process that either encouraged or discouraged the implementation of these solutions.

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International Trend Toward Introducing Cooperative Relationship into Construction Project Management

A review based on Japanese experience

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ABSTRACT

In recent years the acquisition system used in Japanese public construction projects has changed. Competitive bidding system with pre-qualification, Construction Management (CM), multiple-prime contract, Value Engineering and announcement of Bill of Quantities are already being introduced partially.

Such efforts are meant to strengthen the competition among clients, architects, engineers, contractors and suppliers and enhance clarification of contract contents. On the other hand, these changes are to force project participants to some burden of risk, but it is not so explicitly recognized.

In Europe and USA, the existence of the risk seems to be causing some big problems in disputes about construction contracts among participants. Therefore, in construction projects in USA, the dispute prevention system called "Partnering" has been introduced since 1991 to public construction projects.

The author discovered the description that the origin of Partnering principle is Japanese traditional project management technique by mutual trust basis in participants in some documents written by researchers of USA and UK.

At first, this study analyses differences and similarities between Partnering and Japanese traditional project management method. Then, both advantages and

disadvantages of project management method of cooperation such as Partnering will be discussed based on experiences by and characteristics of Japanese construction industry next.

INTRODUCTION

Scope of the study

The focus of this study in treating the subject of "Cooperative relationship" is limited to Partnering. In doing so, the author can clearly explain the concept of "Alliance" or "Long-Term Relationship (LTR)," which the author believes can be defined along the concept of levels of Partnering to be described later.

Method of the study

The study methods used are research of the documents as shown at the end of this paper and analysis of the interview conducted on the persons concerned. Abstracts of listening comprehension investigations are as follows. Listed below are the organizations subjected for the interview research.

1. Building Technology Division, GSA/PBS, Washington, D. C., U.S.A.
2. International Construction Division, The Associated General Contractors of America, Washington, D. C., U.S.A.
3. Construction Management Association of America, Washington, D. C., U.S.A.
4. O'Brien-Kreitzberg & Associates, Inc., N.Y, U.S.A.
5. Division of Engineering Services, National Institute of Services, Washington, D. C., U.S.A.

PPINCIPLES OF PARTNERING

Definition of Partnering

Partnering enables completion of project while solving problems by cooperation of project participants such as client, architect, engineer, general contractor, sub-contractor and supplier.

Those using the conventional problem-solving method do not necessarily persist in seeking after the responsibility and tend to accept ambiguous solutions. Partnering, having no power of legal restriction, It Solution is reached in the form of non-formal statement of mutual agreement signed among the participating executives, as it is executed by their initiatives.

Growth and introduction of Partnering

Partnering, born in America, has dramatically spread on an international scale as the platform of project management already. Let's briefly review the process here.

Before Partnering

Until the 1950's, the main stream of acquisition system for construction project was the traditional "design-bid-build" method in USA. Thus, clients contracted, after completion of drawings, with the lowest responsible bidder at lump sum and fixed price.

During economic recession of the 1960's, speedier processing of projects was demanded in need of sooner bill collection on the part of the client as well as contractor's intention to evade inflation risks.

In addition, buildings became more complicated by technological advances in those days. However, clients did not spare enough design time corresponding to such advances. Projects started the construction still in a low completion level of drawings, and as the result excess of the budget and delay of term of works caused frequent design changes.

In the 1970's, the competition in the American construction market became severer. Project participants insisted upon their own right and strengthened profit pursuit. Thus, there arose a state of antagonism among each other.

Claims increasingly came up in project progress, and the part of them could not be settled among participants, necessitating them to be brought into legal courts. In this way, the American construction business transformed itself into a competitive and high-risk market.

American public clients, too, tried to solve disputes by the court system in those days. However, participants had to face expanding court expenses and suffered direct loss from suspending projects because of dispute processing by courts. In addition, the process created apparent antagonism among participants, leading to an irrevocable break in their business relations. These phenomena contradict with what the project participants should behave toward such primary aims as solid execution of contracts and sound continuation of business relations with each other.

Partnering as ADR

In such situation, the federal government, construction industry, judges and researchers came to positively argue about ways to solve claim problems after the mid-1980's.

According to Poulin's abstract (1985) presented at the ASCE symposium held in Detroit in 1985, it is evident that that studies and enlightenment activities were lively pursued in those days. In addition, U.S. Postal Service (USPS) (1992) reports that USPS itself, The Corps of Engineers, The Associated General Contractors of America (AGC) and The Construction Industry Institute launched taskforce projects for subduing disputes.

There was the same situation around private projects in those days. Private clients were troubled very much by delay in works and excessive costs. Since the mid-1980's, the project management system intended to reinforce cooperative relationship began being applied to projects among those major clients in need of large-scale plants with large-scale general contractors.

The federal government came to recognise need for more efficient method in low cost dispute solutions, and the Federal Congress established enacted Public Law 101-552, "the Administrative Dispute Resolution Act," on November 15, 1990. This law recommended use of ADR techniques onto public projects and aimed at dispute solution and function improvement in all federal agencies. ADR techniques consist of all procedures and their combinations designed to avoid court actions so that the parties involved in disputes can solve problems by voluntary mutual agreement. This means, in other words, that Partnering was established as one of the ADR techniques.

PRACTICAL USE OF PARTNERING

Effect of Partnering practice

Frequent reports tell that introduction of Partnering as ADR leads to reduction of numbers in both court actions and dispute processing expenses.

For example, The Corps of Engineers saw a decrease to only one case and reduced the dispute solution cost from 50.9 million dollars (previous year) to 21 million dollars by introducing Partnering into 200 projects within 1988.

In an example of the Arizona Bureau of Transportation, they introduced Partnering into 96 projects in 1991, and no claim was not brought forth enabling them to achieve a 5 million dollars reduction in dispute solving cost.

Expansion of Partnering Concept

Since 1991, as the original concept of Partnering was being expanded, use of the Partnering method became not only limited as a technique of ADR.

For example, AIA suggested reconciliation with architects and contractors by Partnering. And they declared that the time when the opposition-annoyed clients were annoyed by oppositions was over. On the other hand, AGC positioned Partnering as a strategy to revitalize American construction industry as a more reliable market, world-wise.

The factor contributing to this conceptual expansion seems to lie in the following aspects.

There is no channel of communication in existence that can comprehensively cover connections among all project participants under the usual construction contracts. Some risks are not avoidable because of the incompleteness of the information. Meanwhile, Partnering improves communication among all participants even without direct contracting relations.

Furthermore, Partnering not only reduces claims, but also had the following effects that have become recognized.

-Realization of Total Quality Management

-Realization of risk management

-Advancement of productivity

-Shortening of the term of works

-Reduction of cost

-Improvement of constructability

-Increasing effect of Value Engineering

The international spreading of Partnering

Increased dependency to subcontractors in the execution of construction in UK after 1980's led to such intense problems as entries of non-appropriate suppliers, frequent occurrence of bankruptcy on the part of subcontractors and increase of claims and disputes.

According to Latham (1993), (1994), occurrence of disputes about construction contract became frequent in UK, resembling the earlier situation in the U.S.A. Some immediate measures were thought be necessary for solving this problem and thus introduction of Partnering was proposed as an alternative.

According to Fenn (1999), Partnering is being introduced in Australia, Canada, China, Hong Kong, Iraq, Ireland, Italy, Portugal and Romania. But the definition and range of application of Partnering vary considerably by each country.

Horizontal development of project-based Partnering concept

GSA (1993) introduces only the dispute prevention approach by single project-based Partnering. However, it is natural that, if participants receive profit of project management by the teamwork, they are willing to continue the relation into next projects.

Kubal (1994) calls project-based Partnering "First-Level Partnering." And he calls participants' deployment of its effect onto other projects "Second-Level Partnering".

Second-Level Partnering

In public projects that the open bid must be used for, it is impossible that government and general contractor maintain continuous Partnering. GSA (1993) did not described about this Second-Level Partnering either.

However, regarding the contract on the part of general contractor and sub-contractor, which they can contract freely, it can be said that they make much of continuous business relation for dispute evasion, that lead to quality improvement or productivity improvement.

Global Partnering

McCollough (1993) of AIA shows Global Partnering as a higher-level concept of Second-Level Partnering. He takes the position that if they apply Partnering above the business level of individual project, it becomes useful for economy of global community. In other words, he insists that we should maximally utilize the concept of Partnering so as to overcome various obstacles existing among governments and private organizations.

IS THE ORIGIN OF PARTNERING IN JAPANESE MANAGEMENT METHOD?

From the angle of Japanese perspective of viewing the above-mentioned argument on Partnering, we cannot help feeling that Japanese project management policy much resembles Partnering concept. That is, Partnering concept shares something in common with the principle of building team formation based on the Japanese system of mutual trust. Some documents do discuss the relation of Japanese project management technique and Partnering concept. However, we must be well aware that there has ever been no "Partnering" in Japan in an established style.

Factors of Japanese method of project management that can be related with Partnering

There are only about 17,000 lawyers in Japan for the total population of 1.26 hundred million. When compared with Europe and the USA, the market of the law practitioners in Japan is remarkably small. The background includes dispute-evading characteristic of the nation in terms of its history, culture and religion.

Even company executives and managers, like common people, are not used to lawsuit practice. The same situation exists for participants of construction project. There must be various backgrounds that have nurtured it. In the beginning, a major reason is that architects, engineers and project managers standing in different situations in those projects have received the one and same professional training. In other words, they share technical knowledge at a comparatively high level.

The basic national qualification defining their professional abilities is basically same. Historically, they have been equally tamed under a common purpose and for an incentive for cooperation. With this common mind-set, Japanese building industry was able to maintain considerably strong competition in the international market until recently. In the following sections, I extract elements of Partnering are extracted in a Japanese way of project management system, along with brief comments by the author.

Relation between client and general contractor

In Japan, long-term reciprocal transactions used to be concluded between clients and general contractors in long-term during the period of economic development until the economic bubble collapsed in the late 80's. Japanese clients concluded lump sum at fixed price and fixed term of work contract with general contractors originally without bearing a risk by oneself. And they were satisfied with the service in a closed domestic construction market. This must be an apparent peculiarity in the eyes from overseas.

It was characteristic in Japan until recently that degree of competition between clients and general contractors was low, in contrast to the high ratio of direct "hand-pick" nomination in private building projects as shown in the following data from a RICE survey of such ratio of nomination of Japanese general contractor firms.

Five major companies (annual sale of 1,000,000 million yen/1996-1998 average)................59.9%

Next ten major companies (annual sale of 400,000 up to 1,000,000 million yen/same period).. 52.8%

15 middle class companies (200,000 million up to 400,000 million yen/same period).......... 52.6%

Other minors (below 200,000 million yen/same period)..43.1%

About public projects in Japan, there is a traditional practice of DANGO (business collusion), which is considered to be a problematic and tenacious practice in the past. While measures to restrain that practice have been taken, the degree of competition is still comparatively low.

Relation of general contractor and sub-contractor

Most of Japanese general contractors patronize certain sub-contractors under long-term business contacts, closely organized under the cooperative society called KYORYOKU-KAI. Existence of this type of society, consisting of sub-contractors, is one of the characteristics of Japanese construction system, and its advantage and disadvantage is widely recognized in this country.

Endo and Furusaka (1993) did a research hearing in three veteran project managers at major general contractors. In the research, the number of sub-contractors who were actually engaged in projects in the past five years was examined. In building skeleton construction, every project manager is found to have actually contracted with only one or two sub-contractors. In other words, they contract almost every time with the same sub-contractors.

In brief, on the choice of sub-contractor, project manager does not look for a cheap price by bids. In most cases, they made much of past business relations and contracted with their hand-picked sub-contractors.

As long as such customary business ends up with certain satisfaction for the concerned parties, they do not pursue the work toward better solution under time and cost restraints. If the project is of a conventional type, it is easier and safer for the general contractor to order it to the usual sub-contractor, who already knows the contents of the project well.

Haksever et al. (1996), et al, defined such Japanese business practice as LTR and suggests introduction of its advantageous points to the UK construction industry. Earlier in UK, Bennett, Flanagan and Norman (1987), based on their detailed research of Japanese construction industry, pointed out the same advantage between general contractors and sub-contractors.

Furthermore, this LTR concept is actually the basis of cost management technique of Japanese general contractors. Specifically, general contractors levelled dispersion of rate of return in every project by internally ordering it to KYOURYOKU-KAI members only. Thus, if general contractor's management of the cost becomes difficult, general contractor lets ordering concentrate on some particular sub-contractors of KYORYOKU-KAI and promotes reduction in cost, or tries to hold down the amount of ordering by competition from outsiders of KYORYOKU-KAI.

Differences of Partnering and Japanese method

Differences between Japanese project management technique and Partnering can be clarified as follows.

While Partnering is an artificial technique, Japanese method is something inherent in the Japanese culture and its complicated social systems. Therefore, why participants of Japanese construction projects tend to think that there is no Partnering concept in Japan. There is no limit in confidence relation among Japanese participants for such relation and practice exists as an unwritten law in this country.

PROBLEMS WITHIN JAPANESE CONSTRUCTION INDUSTRY

Japanese construction industry is largely in a difficult situation after the collapse of the "bubble economy." Author's attention is focused on the explicit problems in the trust-based building production system and management system, as described above.

Changes in clients' business mind

At fan apparent change is seen in the changing business mind on the part of clients. After the bubble collapsed, clients of less change-conscious type were financially forced to withdraw from their own market. After the Big Bang, global competition has become severer in every industry as seen in the changing behaviour of finance business and international M&A in auto industry, as well as in clients' behaviour.

Client's competitive power would have to be weakened if they are to procure facilities of lower value than rivals. Clients cannot stay in the market, if they are indifferent to cost performance of their own facilities,

In brief, the market structure where general contractors are tempted to impute cost increase onto the price of products is beginning to collapse.

Changing relationships between general contractor and sub-contractor

Belief in the KYORYOKU-KAI merit is already dispersing. They are becoming aware of the following factors as the apparent demerits of the present KYORYOKU-KAI system.

-Restriction of sub-contractors by general contractor

-Existence of unfair contracts and traditional commercial practices

-Coercion of low cost requirements by general contractors

-Indirect cost to maintain KYORYOKU-KAI societies

-Exclusive "closed" transactions and hurdles to enter in business with new companies

Actually, these demerits were the very property merits adversely in the conventional market environment here.

Conventionally, the contract that general contractors conclude with their clients used to be settled for the amount of contract deposit. Therefore, what the post-order cost management can do is to pursue how they ca restrain reduce overhead cost and restrict the amount of order prices to sub-contractors.

The low level of rate of return and the slump of stock prices on the part of general contractors shows the weakness inherent in this conventional mechanism to overcome their own difficulties. The construction unit price considerably fell by pressure from clients and by such a patch-up cost reducing policy of general contractors. The cost reduction that depends on these conditions is limited.

There followed such phenomena as frequent sub-contractor bankruptcies, and layover of 400,000 workers leaving the construction industry, and a threatening crisis in maintaining the whole production system. In light of the present low level of working conditions of construction workers, loss of skilled workers is predicted to come in the near future.

In addition, both general contractors and sub-contractors do not try to pursue maximization of profit in individual project together as the LTR premise is considered to suffice. They took a meaning of a price of an individual project lightly, resulting in hindrance of sound cost management application.

Furthermore, such a traditional business model of course could not be fully applied to their overseas construction activities. The ratio of overseas construction to occupy in the annual sales of Japanese top-ranking general contractors is less than 10%.

CONCLUSIONS

The author summarize the review the discussions about Partnering in this thesis based on the facts and issues observed in Japanese construction industry.

McCollough sated that a type of Partnering between the Japanese government and private enterprises is a success example of global Partnering as described above. His analysis was such that the both parties are oriented toward a common purpose for them to dominate the arena of competition in global economy by virtue of their version of LTR.

In current Japan, however, few analysts seem to assume that such a characteristic of Japanese construction industry is its strength in business. When the market environment drastically changes as in the case of the collapse of economic bubble, Japanese construction industry can never evade a fate for them to suddenly lose their competitive power. As the result, if a risk clearly exists in a concluded domain of Partnering and cannot be shared, somebody must bear the whole risk intensively based on the original contract.

In other words, Japanese construction industry revealed its on self-contradiction in that they unconsciously try to make a domain only to bear a bigger risk by Partnering for risk reduction. In addition, existence of the domain prevents a switchover to the next system, and hardship of Japanese construction industry is predicted to persistently continue.

Some of general contractors are beginning to cease to award ordering to their conventional cooperative societies and, instead, carry out sub-contractor bids by Internet in order to keep their own competitive power. Thus, material import from overseas is anticipated to increase in future.

A new group who promotes switchover from the lump sum at fixed price system to a business model of Construction Management is coming out. It'd be natural to think that claims and disputes would increase due to such a changeover.

The Japanese overseas construction association has formed a taskforce of Partnering studies, if it's not too late. Japan's judicial circles are deploying the policy to increase lawyers so as to fill the absolute lack in number of lawyers.

Above discussions would clarify how European and American building industry differs from that in Japan in the strategic thinking about cooperative relationship.

The author wonders which side, east and west is going ahead in perfecting the strategy.

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Enhancing project performance by implementing a societal stakeholder culture.

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ABSTRACT

This chapter considers the societal responsibility of developers and contractors towards the general public and describes several recent innovative initiatives used on construction projects to successfully minimise the disruptive nature of contracting and therefore enhance the industry's social contribution in the community.

By adopting a 'stakeholder culture' and with some attention given to impact minimisation, there is the potential for contractors to actually add value to the community that they work in. Creating a more harmonious relationship with the public is not necessarily entirely altruistic, since improved profitability and performance are likely to result from a more enlightened, socially-accountable and responsible approach to contracting.

SOCIETAL ASPECTS OF MARKETING AND PUBLIC RELATIONS

The construction industry in the United Kingdom generally suffers from a poor public image, due partly to the disruptive effect that construction operations have upon the community. . Baldry (1997) states that construction is the most visible of industries and conducts its affairs almost totally in the public arena. Contractors are usually uninvited and unwelcome neighbours in most communities. Rolt (1976) aptly illustrates that this is not just a recent phenomenon, alluding to a 19th century quotation, *"I would rather meet a highwayman, or see a burglar on my premises, than an engineer."*

Colonel Sibthorp, Member of Parliament for Lincoln 1833.

A fundamental prerequisite to accountable and responsible working practices is the appreciation and application by every construction project employee of the societal and symbiotic aspects of marketing and public relations.

Traditionally, the construction industry has tended to restrict its marketing and public relations activities to a dedicated individual or department, specifically engaged to promote business and maintain good relationships with key clients. An all-embracing 'stakeholder' approach that fully considers the publics interests has so far yet to be fully realised.

The United Kingdom's Institute of Public Relations (IPR) define public relations as; *The deliberate, planned and sustained effort to establish and maintain goodwill and mutual understanding between an organisation and its publics.*

There exists an apparent dichotomy between the project operational activities of many contractors and their head office formulated marketing and public relations intentions. Pearce (1998) suggests that all staff operate within a network and that; *"Everyone should be tuned to become part of a very big corporate ear-to-the-ground."* Hillebrandt and Cannon (1990) suggest that orientation to the marketing concept in construction has been slow and that it is perhaps the least well developed of the management activities.

It is understood that contractors expend considerable amounts of money and other resources from their marketing budgets to maintain public awareness and client credibility. The same contractors however apparently ignore the detrimental effect that their often inconsiderate site based practices have upon the public.

Eksteen (1999) argues that the construction industry needs to become sensitised to its market and adopt a different mindset to meet the increasing demands such as conservation, environmental sensitivity, health and safety.

It could be argued that the construction industry has understood the multiplicity of the concept of public relations even less than it has understood the essential tenets of marketing. Public relations embraces public affairs, corporate affairs, community affairs, community relations and corporate communications. According to White (1991) *"Public relations concerns are with relations of one group to another, and with the interplay of conflicting and competing interests in social relationships".*

It could also be argued that contractors need to instigate a 'charm offensive' before and during their construction operations to develop their credibility and mitigate the negative impact upon their public. Friedman (1970) however suggests that the social responsibility of organisations is limited to the ethical management of its resources i.e. maximising its profit potential without recourse to fraudulent or deceptive business practices. This 'agency' approach is in stark contrast to the wider 'stakeholder' approaches employed by the more socially-responsible and accountable organisations who recognise that their actions or inactions transcend mere compliance with basic legal and moral obligations.

However, as Barthorpe (1999) suggests companies need not conduct their business in the community entirely out of altruistic or philanthropic motives, it makes sound business sense to foster good relations with the local community. Public relations should therefore be considered a strategic management tool which organisations could use to establish and improve their reputation. Organisations should take a proactive 'stakeholder' approach to maintain good public relations with the community.

DEVELOPING THE STAKEHOLDER CONCEPT

According to Freeman (1984) stakeholders are, *'any group or individual who can affect or is affected by the achievement of an organisation's purpose'*. Baldry (1998) contends that all construction activity has associated with it a body of interested parties known as stakeholders who have a conspicuous interest in the construction process.

Preece *et. al.* (1998) contend that the development of the concept of stakeholders originated in the late 1960's. The comparatively narrow perspective proposed in the 'production view' held at the time suggested that an organisations stakeholders were limited to its suppliers and customers (external stakeholders).

From the 1980's, concurrent with the development away from the 'Scientific Management' approach towards the 'Human Resource Management' approach, stakeholders also included shareholders and employees (internal stakeholders) in what Freeman (1985) termed the 'managerial view'.

The 1990's saw a significant increase in global public concern for conservation and environmental exploitation. This heightened global awareness forced organisations to adopt more environmentally-friendly business methods and accept the wider general public among its stakeholders in what may be termed a 'societally-responsible view' (societal stakeholders).

Organisations that accept their corporate social responsibilities do not consider the general public's interests as mutually exclusive or in competition with their corporate goals. Previously, environmental pressure groups and disaffected communities were often ignored and regarded as peripheral but more recently, have attracted growing public support and have assumed a potent influence upon corporate affairs.

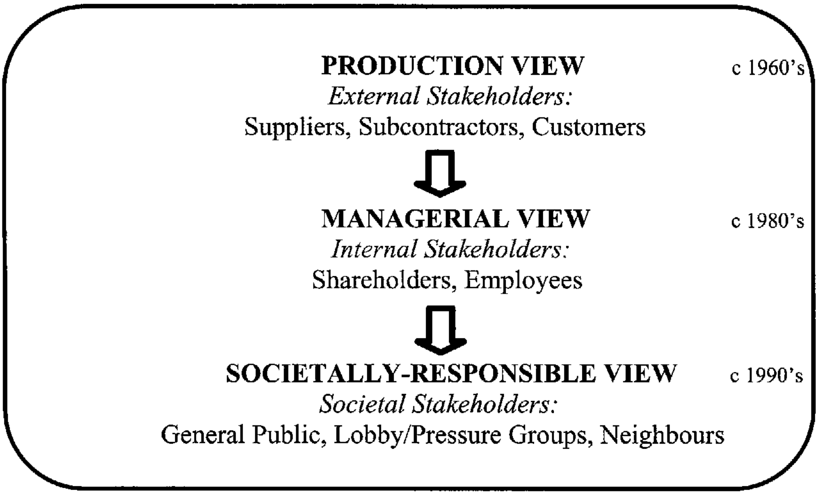

Figure 1 Stakeholder Network Development

Stakeholder Analysis

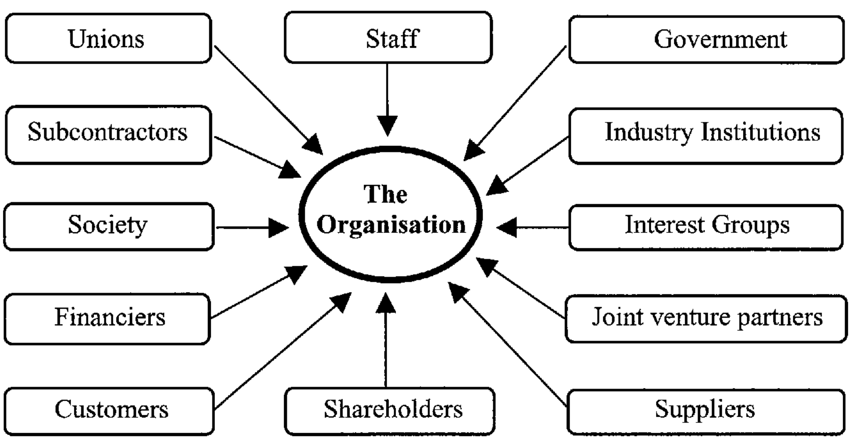

Figure 2 A Stakeholder map for construction organisations Source: Preece *et. al.* (1998) p11

According to Fill (1999) the first step in stakeholder analysis is to list all the stakeholders and then position them on a map. Preece *et.al.* (1998) suggest that a stakeholder analysis has to go further than just categorising the types of stakeholders. They state that there has to be an understanding of the potential influence of each particular stakeholder and that an analysis has to accommodate the impact of change likely in the dynamic environment experienced by the construction industry. Freeman (1984) further suggests that the identification of the various stakeholders interests and power is important so that an appropriate operational strategy is formulated. Certain organisations or individuals within a stakeholder network may, according to Fill (1999) yield a disproportionate level of power and influence.

The stakeholder network for the construction industry is generally more complicated than most organisations from other industry's because contractors usually operate on two levels; centrally, there exists a permanent national or regional office where off-site management and support functions are carried out. At another level, project operational functions are performed on a site, usually over a limited time period. This Temporary Multi Organisation (TMO) as Liu and Fellows (1999) describe this phenomenon, fosters an exponential expansion of organisational complexities. The extensive use of subcontracting and in particular the more recent advent of Private Finance Initiative (PFI) projects has significantly widened the network of construction stakeholders, including financiers, Government agencies and public end-users.

DEVELOPING A STAKEHOLDER CULTURE

Before applying the concept of 'stakeholder' to 'culture' it is important to appreciate the development and definitions of the 'culture' component in context. Culture has been described by Barthorpe *et. al.* (2000) as a pluralistic concept. The evolution and development of the generic definition of culture, first advanced by British anthropologist Edward Tylor in 1871 as; *'that complex whole which includes knowledge, beliefs, art, morals, law, custom and any other capabilities and habits acquired by man as a member of society'* has expanded significantly during the latter half of the 20th century (Brown 1995).

Writers such as (Schein 1992; Hofstede 1980, 1991; Handy 1993; Deal and Kennedy 1982 and more recently, Peters and Waterman 1982) have provided valuable insights into the understanding of the definitions and determinants of organisational or corporate culture. The culture of an organisation strongly influences its behaviour in the community. Construction is a very visible industry and its activities are closely scrutinised by the public. Scholtz (1987) contends that corporate culture is, *'... the implicit, invisible, intrinsic and informal consciousness of the organisation which guides the behaviour of the individuals and which shapes itself out of their behaviour'*.

Drennan (1992) succinctly states that culture is, '... *how things are done around here. It is what is typical of the organisation, the habits, the prevailing attitudes, the grown-up pattern of accepted and expected behaviour'*. Burrack (1995) suggests that corporate culture, '... *is the glue that holds the corporate community together. It in effect, represents the organisations social energy and personality'*. It can be appreciated therefore that there is an inextricable link between the culture of an organisation and its external behaviour, its 'outgoing message' to the public, its societal stakeholders.

IMPLEMENTING A SOCIETAL STAKEHOLDER CAMPAIGN

Due to their generally disruptive nature, construction projects are uninvited, unwelcomed and unwanted in many existing communities. Contractors that adopt a societal stakeholder campaign however can foster a mutually beneficial partnership with their neighbours and significantly improve the tarnished image usually associated with the construction industry.

Project managers in particular are responsible not only for the quality and timely execution of their projects, but also for 'outgoing message' their working practices have upon their neighbours. Project managers in particular and the site workforce in general are, in effect 'ambassadors' for their company and for the construction industry. In particularly sensitive neighbourhoods, a project-based, dedicated community liaison person should be appointed. Ideally, such an individual who is familiar with the construction process and an excellent communicator would provide an invaluable role, able to establish mutually beneficial project objectives, thus enhancing project performance and adding value to the community.

A societal stakeholder campaign would necessitate an impact minimisation strategy being formulated at the pre-construction stage. The logistical aspects involving vehicular movement, waste minimisation and security would require particular attention. Construction projects are often sited in locations prone to criminal or vandal attention. The reciprocal benefits to the contractor of maintaining a good relationship with the community evidence themselves in receiving greater co-operation and tolerance to site activities causing noise, dust and disruption.

Preece *et. al.* (1998) contend that as communities become more sophisticated, they acquire the means to disrupt, delay or ultimately stop projects or conversely help expedite them. Construction activities are subject to the control of a vast array of statutory legal obligations, generally associated with safety or environmental issues, specifically intended to protect the general public. A significant amount of construction work in the UK is commissioned from public and private pension fund sources. Since July 2000, pension funds and local authority pension schemes have been required by law to publish in their Statements of Investment Principles the extent to which social, environmental and ethical considerations are taken into account in their investment strategies (DETR 2000). In some cases, over and above any legal requirements, project-specific conditions have been imposed, with the mutual agreement of the contractor and the community. An innovative 'residents charter' agreement was established between four parties at a prestigious hotel project (client, development agency, contractor and residents) in South Wales, UK. (Contract Journal 1997). The unique 36 point Residents' Charter was designed to ensure harmony with the residents during construction, while offering quality job opportunities to local people afterwards. (RFH Residents Charter 1997). Strict rules are encompassed in the Residents' Charter to minimise disruption to the residents and cash penalties are imposed if certain regulations are breached by the contractor. A summary of the Residents Charter is provided below:

- ❑ Designed to ensure harmony with residents during construction.
- ❑ Training and job opportunities to local people after construction.
- ❑ Strict rules minimising disruption to residents.
- ❑ Cash penalties for breach of certain regulations.
- ❑ Construction traffic diverted from local homes.
- ❑ Fortnightly cleaning of nearby resident's windows.
- ❑ Construction vehicles washed before leaving site.
- ❑ Air quality monitoring.
- ❑ CCTV monitoring of activities and fines imposed for breaches.
- ❑ Regular meetings with community representatives.
- ❑ Special promotions offering resident's access to hotel facilities.
- ❑ Fines imposed will be used to benefit local community projects.

RFH intended the Charter to demonstrate that the company is serious about working in partnership with neighbours, not only during construction but also as a member of the local community when they are opened for business.

Although many construction organisations adopt socially responsible and environmentally sensitive working practices, the construction industry generally has a relatively myopic understanding of a societal stakeholder culture. Many examples of exemplary community projects undertaken by exemplary contractors do exist, but in general the construction industry has instigated community-enhancing initiatives on an *ad hoc* basis.

Considerate Constructors Scheme

Arguably the greatest contribution of any initiative to improve the image of the UK construction industry and enhance the community stakeholder culture has been the establishment of the Considerate Constructors Scheme (CCS) in 1997. The impetus for the CCS was initiated from the seminal report, *'Constructing the Team'* (Latham 1994) and from direct recommendations in the *'Constructing a better image'* report (Construction Industry Board 1997). *'The CCS is a national initiative designed to improve the image of construction through better management and presentation of sites, with the emphasis on improving relationships with the local community'* (CCS 1997).

The Scheme implements an eight point Code of Considerate Practice (CCS 1997):

- **Considerate**
- **Environmentally Aware**
- **Clean**
- **Good Neighbour**
- **Respectful**
- **Safe**
- **Responsible**
- **Accountable**

Since its inception in 1997, over 4000 sites have registered with the Scheme. At least half of all current registrations are initiated by the clients, who often make it a contractual obligation in their terms of engagement (CCS 2001a). The Scheme's uptake has risen significantly since August 2000, registering 1233 sites, worth £4.8 billion (CCS 2001 b). Compliance with the code of practice is assessed by CCS monitors and national awards are presented to recognise and reward those contractors attaining exceptional standards of performance. Nick Raynsford, the previous UK Minister for Construction states in the CCS promotional literature :

The establishment of the Considerate Constructors Scheme provides a real opportunity for the industry to improve its image. It has the full support of every sector of construction and is backed by the Government, who recognise the importance of the industry demonstrating consideration for both the public and the environment.

I want the construction industry to be increasingly seen as a force for good – environmentally as well as economically. The Considerate Constructors Scheme is one way in which the industry can use its professionalism and technical expertise to work for the benefit of all. (CCS 1997)

In recent years many contractors have excelled in implementing community-enhancing initiatives. Recent examples include; establishing site-base charities to support local causes. Liaising with schools to promote careers in construction and support technology and engineering projects. Providing site based training and employment. Showing an interest in local social events such as town carnivals, sponsoring sports events and organising open-days for site visits as well as providing materials and manpower for needy causes such as homeless shelters.

CONCLUSIONS

This chapter has discussed the potential for enhancing project performance by the implementation of a societal stakeholder culture. The societal aspects of marketing and public relations have yet to be fully realised by the construction industry, who have traditionally mainly considered marketing as a selling function. Organisations that take a proactive stakeholder approach to maintain good community relations do not need to do so out of entirely altruistic or philanthropic motives, since it makes sound business sense to foster good relations with the local communities.

The comparatively narrow concept of stakeholders held until the 1960's has developed more recently by many socially responsible organisations towards an all-embracing concept that acknowledges a societal network of vicarious stakeholders.

There is an increasing level of expectation from clients, local authorities and the general public for construction projects to attain higher standards of environmental performance. Clients in particular are increasingly image-conscious and require their contractors to uphold their corporate standards and values.

With its 'Code of Considerate Practice' and 'Best Practice' guidelines, the Considerate Constructors Scheme provides an ideal framework for the construction industry to implement a societal stakeholder culture and demonstrate a professional, community enhancing and environmentally sensitive commitment. The potential for community involvement is particularly significant where partnerships are forged between construction organisations and schools, where opportunities to educate and excite an interest in engineering and technology can be instrumental in promoting the considerable achievements and career opportunities in the construction industry.

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The characteristics of periodic and project prequalification practices in the UK

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ABSTRACT

Construction contractor prequalification can be categorised into periodic prequalification and project prequalification. The first is performed to develop a standing list of contractors relevant for a certain periodic time frame, which can be used by a client for short listing or invitation to bid. On the other hand project prequalification is performed to develop a list for a particular project, on a project by project basis, before invitation to bid. The purpose of this paper is to present the differences and similarities of these prequalification practices in the UK using data collected via a structured questionnaire survey and literature reviews. To obtain a broad range of practical experience of prequalification systems the sample consists of contractors and clients. Additionally the influence of project characteristics such as project size and type on the development of both prequalification systems is investigated. This paper also discusses outsourcing contractor prequalification practices as an alternative method to reduce evaluation cost by sharing the cost between contractors and clients.

INTRODUCTION

Practically there are two main types of prequalification systems in the UK construction industry, namely, standing list and project list or ad-hoc list prequalification systems. The main difference between both types is the timing of evaluation of contractors' data. The first is performed to develop a standing list of contractors relevant for a certain periodic time frame, which can be used by a client for short listing or invitation to bid. On the other hand, project prequalification is performed to develop a list for a particular project, on a project by project basis, before invitation to bid (Hatush 1996; Jennings and Holt 1998; Ng 1996).

The purpose of this paper is to present the differences and similarities of these prequalification practices in the UK using data collected via a structured questionnaire survey and literature review. To obtain a broad range of practical experience of prequalification systems the sample consists of clients and contractors. Additionally, the influence of project characteristics, such as project size and type, on the development of both prequalification systems is investigated. This paper also discusses outsourcing prequalification practices as an alternative method to reduce evaluation cost by sharing the cost between clients and contractors .

METHODOLOGY

The survey was carried out through literature review and postal questionnaire survey. Two similar types of questionnaire survey were designed for clients and contractors in order to obtain a broad range of response. Each questionnaire consists of three sections. Section one was intended to elicit the characteristics of respondents and their organisations or firms and can be used for cross analysis of responses on the basis of categorical data. Section two, the main part of questionnaire relating to the characteristics of prequalification systems, sought numerical and categorical data using a Likert scale, as well as including open questions depending on the nature of the answer needed. A blank or "not known" answer is treated as a missing value. Section three asked for comments and suggestions as additional information.

The questionnaires were distributed to 312 client organisations or firms and 332 construction firms in the UK. A total of 136 questionnaires were returned, representing an overall response rate of 21%. The returned questionnaires represent 85 client organisations/ firms and 51 contractor firms in terms of usable data. Statistical software (SPSS version 10) was used to analyse the questionnaire response. Descriptive statistical analyses were used for the categorical data excluding ordinal data, while ordinal data were analysed using mean impact or importance ranking variables. Furthermore, Spearman Rank Correlation Coefficient (SRCC) was employed to analyse the relationship between periodic and project prequalification for each group of ranking variables.

LITERATURE REVIEW

A major drawback of the periodic prequalification system is an information gap between the time prequalification is performed and the time when the approved list of contractors is developed for a tender list. It might happen that contractor capacity would no longer meet the construction workload requirements of a particular project due to current project workloads (Holt et al. 1995; Russell 1996). In other words, working capital, resources or key personnel may have reduced to a level that may significantly influence a contractor's project performance in respect of time, cost and quality due to their other ongoing projects. Additionally, it is difficult for clients to carry out detailed investigation related to project specific requirements or objectives. Briefly, historical data from previous projects are the only main focus of assessment.

Categorising contractor capability on the basis of project size and type, however, can reduce the information gap, and can also be useful when clients have a certain number and size of routine projects annually; such categorisations can be found in Japan (Kunishima and Shoji 1996), or Indonesia (Indonesian Government 1994). Moreover, at the tendering stage, clients could check only the suitability of contractors' remaining capacity. This may decrease the effort of evaluation in respect of both time and cost.

There is a significant difference in terms of the amount of clients' effort and resources required between annual periodic prequalification and project prequalification. Evaluation cost of project prequalification per contractor is typically ten times greater than annual periodic prequalification and evaluation effort is approximately 8 person-hours/ contractor per annum compared with 25 person-hours/ contractor/ project for project prequalification (Russell 1996). For clients having a number of projects annually, there are disadvantages to using project prequalification, as they have to repeat the prequalification process for every project (Hatush 1996).

One benefit of project prequalification is that clients might have an opportunity to obtain current data in more detail, not only in respect of internal factors of contractor financial and technical capability, but also in respect of external factors that can influence the performance of a contractor during the construction process, such as location, interest rates and regulations (Russell 1996). This type of prequalification is suitable for large complex projects or those which are specialised and/ or non-repetitive in nature (Ng 1996).

Furthermore, other criticisms about prequalification practice in the UK came from the Latham report (Latham 1994). Implementation of prequalification systems tend to be repetitive. Contractors are asked to submit similar documents to every client and keeping separate lists incurs relatively large cost, including maintenance of prequalification records, information processing, issuing prequalification certificates and office storage. Such duplication of effort and maintenance of the lists are a wasteful burden for the construction industry. The report recommends centralisation of prequalification through a third party. In order to implement this recommendation, a National Qualification System was established by the then Department of Environment, Transport and the Regions (DETR) in 1998 as the single national database of registered contractors. Currently the prequalification system is managed by the Capita group under the name of Constructionline, although ownership still remains with the DETR. According to the Constructors Liaison Group, repetitive qualification procedures cost the industry £130 million annually and Constructionline has the potential to save about 75% of prequalification cost, if periodic prequalification is outsourced to them instead of clients using in-house methods (Constructionline 2001).

According to a previous survey (Wong et al. 1999), the industry has, however, not responded to the system and used it confidently. There are several factors why the list is not widely used, including lack of flexibility and lack of tolerance to clients' specific requirement such as consideration of clients' preferences, geographical concerns, and project specific requirements.

CHARACTERISTICS OF RESPONDENTS

Almost 40% (33) of respondents from client organisations/ firms are Quantity Surveyors, with Civil and Structural engineers representing 25% (21) and Architects 12% (10). About 90% of respondents have been involved with prequalification for more than 5 years and deal with more than 5 projects on this basis per annum. They are pre-dominantly engaged in building/ industrial building (about 70% (62)) followed by 30% (23) in civil engineering/ infrastructure. 90% of clients come from the public sector, with the remaining 10% from the private sector

While the Businessman category represents the highest number of contractor respondents (40% (21)), most of them come from marketing division, and Civil/ structural engineers represent about 30% (16). 82% (42) of respondents have had more than 5 years experience of prequalification and are involved with more than 10 prequalification projects annually, which is relatively similar to client respondents. In terms of type of project, contractor respondents are involved almost equally in building/ housing and civil engineering/ infrastructure. Moreover, response rates from private and public sector contractors are also nearly equal.

RESULTS AND DISCUSSION

Decision criteria for contractor prequalification

It is not surprising to find that financial strength, past experience, past performance, and Health and Safety record are commonly used by clients for their periodic and project prequalification, as rated by 95% of the respondents. But there are differences between periodic prequalification and project prequalification. For example, the criteria of managerial and technical strength (86%), suitable and sufficient resources (80%) and current work load (58%) are used less in periodic prequalification than in project prequalification, where they are rated at 94%, 91%, 73% respectively. It is reasonable that the difference is because the capacities of a contractor required to conform to project objectives are relatively easier analysed at the stage of project prequalification. In other words, the relevant use, at the tender stage, of a contractor evaluation result obtained from periodic prequalification relies on the time span between the stage of periodic prequalification and the submission of tender. It means that the less the time gap, the more the information is relevant to use. Related to this time span, the results of this survey show that the majority of clients (50%) still only reassess contractors every 3 years or more, 25% every 2 years and only 25% every year.

Furthermore, a similar result is obtained if the data are categorised by public and private sectors. The only differences are the additional criteria specified by respondents in terms of regulations such as equal opportunities. "Equal opportunities" was not chosen by private respondents, while the public sector included this in their decision criteria. However, environmental policy and quality assurance are included by both sectors. However, these are rated very low (below 10%).

Supporting the result above, about 80% of client respondents supported the statement that the purpose of prequalification was "to eliminate the incompetent, over extended, underfinanced and inexperienced contractors in terms of performing a certain level of project tasks", 73% "to minimise risks including time delay, cost overrun, and inferior quality", while about 50% agreed that the purpose was "to comply with regulations" or "standard procedure".

References/ bases of design, development and evaluation of decision criteria

Factors that can be used for references and bases of design, development and evaluation of decision criteria were gathered from a literature review of previous studies (Hatush 1996; Merna and Smith 1990; Ng 1996; Russell 1996; Russell and Skibniewski 1988) and respondents were asked their experience or opinion of use of the references and bases, and the degree of impact on weighting/ scoring decision criteria. Based on scale of 1-3, ranging from low to high impact, project size and type have the highest rank with mean response between moderate and high impact level (around 2.5) for both prequalification types and for either comparison among overall data, or by categorising into type of organisation (i.e. public and private). For brevity, only overall data and organisation category of the mean impacts and correlation coefficients are shown in Table 1.

Similar results are obtained for the reason for contractors being involved with prequalification, where project size and type are considered as having slightly moderate importance (mean impact 2.16 and 2.34 respectively), and within the rank of the top four with "the opportunity of winning a contract and need for continuity in employment of key personnel and work force" (2.68) and "relationship with client" (2.24). In respect of the importance of project type factor, contractors tend to specialise in a relatively narrow range of construction types, because of the radically different equipment requirements, construction methods, trade and supervisory skills, contract provisions, and financial arrangements involved with different project types (Clough 1986).

In addition to project size, according to client respondents, most of whom come from the public sector, the use of periodic prequalification tends to increase as the size of the project becomes smaller. On the other hand, the use of project prequalification is fairly constant (40%-55%) regardless of project value. For project value above £5 million, 50% of clients employ project prequalification and only around 20% periodic prequalification. The use of similar proportions of project prequalification can be understandable, as according to some respondents, project prequalification may be needed to meet specific requirements even though the project size is small, or if the project value is above the threshold of €5 million (equivalent to around £3.7 million), at which contracts are subject to European Procurement Directives.

Table 1 The mean impact of references/ bases

References/ bases	Mean impact on weighting/ scoring decision criteria					
	Overall data		Private		Public	
	a	b	a	b	A	b
	N=99	N=88	N=25	N=24	N=74	N=64
Project objectives	1.78	2.16	2.00	2.50	1.70	2.03
Project size	2.37	2.47	2.24	2.33	2.42	2.52
Project type	2.37	2.47	2.08	2.54	2.47	2.44
Individual experience	2.13	2.39	2.00	2.71	2.18	2.27
Client objectives	1.87	2.05	2.20	2.46	1.76	1.89
Risk analysis	1.55	1.73	1.68	2.29	1.50	1.52
Public accountability	1.94	1.66	1.48	1.42	2.09	1.75
Correlation coefficient	0.645		0.696		0.664	
Significance level	0.032*		0.017*		0.026*	

Note: a: periodic prequalification

b: project prequalification

*) significant at the level 0.05 (2-tailed)

Contractor respondents also confirm that clients use relatively smaller project sizes for periodic prequalification than project prequalification, indicated by a mean value of contracts of £18 million for periodic prequalification and £46 million for project prequalification for the same number (35) of awarded projects for each type of prequalification. Therefore, project size becomes one of the influential variables in respect of design of the decision criteria.

When the SRCC was employed for the overall data and the organisation categories in respect of the mean impact of references/ bases on weighting/ scoring decision criteria, correlation factors between periodic prequalification and project prequalification are significant. But public accountability is more influential in periodic prequalification, while project objectives are more significant in project prequalification (see Table 1). Moreover, public accountability is only more important in periodic prequalification as far as public clients are concerned. In comparison, the private sector is less concerned with this factor for both prequalification types as indicated by the lowest mean impact.

Another result related to this factor is that about 50% of client respondents, most of whom come from the public sector, agree that the purpose of prequalification is either "to comply with regulations" or "standard procedure". Furthermore, project and client objectives are more influential in project prequalification, since a particular project could be well defined at the stage of project prequalification.

Individual experience has also more impact in respect of project prequalification due to necessity of prequalifiers who have relevant experience.

The relationship between project performance and prequalification process

Using a relative importance scale of 1 to 3, both client and contractor respondents suggest implementation of project prequalification has slightly better impact on project performance (cost:2.21, time:2.12 and quality: 2.15) than periodic prequalification (cost:2.05, time:2.01 and quality: 2.18) and there is no significant rank correlation (probability value of 0.667 at the 5% significant level for two-tailed test) between both types as indicated by the SRCC of 0.5.

Additionally, quality performance is the highest rank when periodic prequalification is used, while cost performance is the highest for project prequalification. Time performance is the lowest rank for both types of prequalification. In relation to cost and time performance in the Key Performance Indicators (KPI) issued by the Construction Best Practice Programme, construction time performance is also lower than cost performance, where 80% of construction firms, for instance, achieved a time overrun of less than 10%, while at the same time they achieved cost overrun of less than 5% (KPI 1999).

There are several factors that may influence the success of collection and evaluation of contractor data that probably influences a contractor's performance. Firstly, the number and types of data collection techniques that are employed should be considered (Ng 1996; Preece et al. 1997; Russell 1996). Only around 45% of clients employ either three or more methods in periodic prequalification compared with about 70% in project prequalification. In detail, Table 2 shows that frequency of usage differs between periodic and project prequalification, where "questionnaire form with data endorsed by related parties" is widely used for gathering contractors' data by both public and private clients for both prequalification types. For project prequalification, interview and presentation are more suitable as additional ways to collect data. Third parties' information is used at moderate level by both groups of clients for both prequalification types, while visit to office is more favoured by private clients.

Secondly, the types of tools/ models for evaluation of contractor data should be considered (Hatush 1996; Ng 1996). As can be seen in Table 3, 50% use simple aggregate rating (dimensional weighting/ scoring) in periodic prequalification compared with 74% in project prequalification. Conversely, 73% use a checklist approach (e.g. Yes or No) in periodic prequalification, while almost 60% use it in project prequalification. Simple aggregate rating, used more in project prequalification, is a better measurement technique than a checklist, because in dimensional weighting clients can distinguish the relative degree of importance of each decision based on their objectives (Russell and Skibniewski 1988). Additionally, other advanced models including multi-attribute analysis, knowledge based system or case-based reasoning have a frequency of use of less than 10% for periodic prequalification and less than 15% for project prequalification.

Table 2 Relationship between data collection method and prequalification type

Data collection method	Frequency of usage					
	Overall		Private		Public	
	a	b	a	b	a	b
	N=118	N=99	N=28	N=25	N=90	N=73
Questionnaire form with data endorsed by related parties (e.g. accountants, previous clients, bank etc.)	88.1%	82.0%	85.7%	76.9%	88.9%	83.8%
Interview	28.0%	63.0%	50.0%	73.1%	21.1%	59.5%
Visit to the office	20.3%	34.0%	42.9%	53.8%	13.3%	27.0%
Contractors' presentation	28.8%	66.7%	39.3%	73.1%	25.6%	64.4%
Third parties' information (e.g. surety/ insurance company, financial consultant report)	46.6%	47.0%	46.4%	42.3%	46.7%	48.6%

Note: a: periodic prequalification

b: project prequalification

Table 3 Relationship between tool/ model used for evaluation and prequalification type

Tool/ model for evaluation	Frequency of usage	
	Periodic Prequalification N=118	Project Prequalification N=99
Simple aggregate rating (dimensional weighting/ scoring)	50.00%	74.60%
Checklist approach (e.g. Yes or No)	73.20%	58.20%

The third factor is the evaluation time to review the effectiveness of prequalification systems regarding their impact on the awarded contractors' performance (Holt et al. 1995) and the next factor is availability of formal prequalification guidelines (Holt et al. 1995; Ng 1996). The routine evaluation of periodic prequalification (65%) is slightly lower than project prequalification (70%). Moreover, contractor respondents indicate that only 6% clients usually provide formal guidelines for periodic prequalification (24% sometimes and 70% rarely) compared with 11% for project prequalification (28% sometimes and 61% rarely), while 50% of client respondents provide formal guidelines for periodic prequalification compared with 60% for project prequalification. It is, therefore, not surprising that most contractor respondents (67%) did not know the types of models or tools used by clients for evaluation of their data. The last factor is the resources required to prepare a prequalification proposal indicated by how much time and cost the clients spend (Russell 1996). As found in this survey, 85% of client respondents spend less than 10 man-hours for preparation of a periodic prequalification system compared with 70% for a project prequalification proposal of the same cost.

Constructionline

As mentioned before, Constructionline produces a list of registered contractors and may be considered as outsourcing prequalification carried out by a third party; the list is mainly intended for use in the public sector, but it is not mandatory.

Half of the client respondents are members of Constructionline, while almost 90% of contractor respondents are registered. Furthermore, of 77 respondents from both client and contractor categories, 14% indicate clients usually accept the list without further prequalification, 47% sometimes, and 39% never, while of 68 respondents from the same categories, 26% indicate clients accept the list but with further prequalification, 59% sometimes, and 15% never. These findings show an increase in acceptance of this list compared with a previous survey (Wong et al. 1999) which found only 5% (3) of clients used the list, 45% (27) used both the list and their own prequalification system, and 50% (30) used their own system.

Some reasons from clients who do not fully utilise the list, which are similar to comments from the previous survey (Wong et al. 1999), are as follows:

- The system is not concerned with regulations such as statutory requirements of Health and Safety, equal opportunities considerations, certification of quality assurance system (e.g. ISO 9000) and environmental management system (e.g. ISO 14000).

- The system provides inadequate information in respect of size, and specific and geographical operation of contractors, and only low grade checks on various criteria or not as detailed as the clients' requirements (e.g. insurance out of date, cash-flow problems and other financial matters)

- Relationships between clients and contractors are already well established.

Reasons to use this scheme, however, include that the list can be used for a first filter and the scheme reduces questionnaire information and duplication.

Around a third of qualified contractors on the list, from either periodic prequalification or project prequalification, are awarded contracts. Therefore, it can be argued that almost 70% of those who submitted prequalification proposals wasted time and money, especially if they had to submit similar prequalification proposals to different clients. However, it is not realistic that clients only rely on the qualified contractor list of a third party like Constructionline, since every project has different objectives and requirements as well as the information gap which exists, as discussed before.

Regarding this matter, one possible approach would be to include periodic prequalification and project prequalification within one system of prequalification. This means periodic prequalification applied at the outsourcing level would mainly deal with historical data such as financial strength, past performance and past experience, and project prequalification applied at the project level would mainly be concerned with current data workload such as current financial position and current remaining resources as criteria which have to meet specified requirements. To link between both prequalification types, the contractor data at the outsourcing level would be categorised into project characteristics such as project size and type, into client characteristics such as organisation type (i.e. private and public), and into environmental characteristics such as geographical experiences (e.g. local, national, and international operation) and regulations. Thus, clients would not evaluate the whole contractors' data but only the specific requirements related to their particular project. But the third parties who carry out such prequalification must be accepted in the construction industry.

CONCLUSION

It can be concluded that despite differences between periodic and project prequalification, there are similarities between both types. In both types clients usually include financial strength, past experience, past performance and Health & Safety record as prequalification criteria, while clients are more concerned with the importance of managerial and technical strength, suitable and sufficient resources and workload, as criteria to be included in project prequalification. Furthermore, project size and type are suitable references for the development of prequalification criteria and also were shown to have the highest importance factors in respect of weighting in both prequalification types. Additionally, public accountability is more important in periodic prequalification, particularly in public organisations. On the other hand, project objectives are more relevant to project prequalification.

The data suggest that contractor performance is slightly better if contractors are qualified through project prequalification. There are some reasons to explain this difference, as a result of the different approaches used for collection and evaluation of contractors' data including:

- The use of contractors data collection techniques, either individually or combined;
- The utilisation of evaluation models;
- The regularity of evaluation of prequalification system performance;
- The availability of formal published guidelines for each prequalification system; and
- The efforts and resources required for preparation of prequalification proposals.

A combination of implementation of project prequalification at the in-house level and periodic prequalification system at the outsourcing level into an integrated prequalification system has potential to save time and money. As a result, improvement of prequalification systems should be focussed on periodic prequalification in order to find the relationship between historical data closely relevant to periodic prequalification data and the data that are commonly required at the level of a particular project. In other words, historical data are related to finding information about contractor capability at the stage of periodic prequalification which are still usable at the stage of project prequalification. Therefore, further evaluation at the stage of project prequalification can be concentrated on current contractors' data that are relevant to obtain the information regarding contractor capacity which can meet project specific requirements or objectives.

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Why Croatian Construction Companies Do Not Implement a Marketing Concept?

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ABSTRACT

Implementation of marketing philosophy within Croatian construction companies is not satisfactory. There are many reasons for this situation. Although the lack of work is the most significant characteristic of the Croatian construction market, very little has been done (on the company level) to improve marketing methods and techniques. But, now as the Croatian companies are in a process of market transformation, they are beginning to realise the importance of being "market oriented" Unfortunately, to often, they not only lack knowledge but also real incentive to implement the "new approach".

The authors are conducting an empirical study aimed at assessing the level of marketing within the Croatian construction industry in order to define the best approach (most appropriate) to the "marketing concept for the construction industry".

INTRODUCTION

The Croatian construction industry today is basically marked by a chronic lack of work, but very little is being done to find new markets for placing products and services. The owners and/or managers of most Croatian construction companies still operate on principles that they have used for decades. Work is still (especially in small and middle-sized companies) acquired "through connections" using friendship and similar informal kinds of business operation. Large companies as a rule secure most of their work through public competitions, nonetheless neglecting contemporary marketing principles.

Does being market oriented pay off? Recent evidence suggests that it does, at least in a highly developed economy like the United States. Several studies involving a total of more than 400 business units in a variety of industries indicate that a market orientation has a significant positive effect on various dimensions of performance, including return on assets, sales growth and new product success (Walker, 1996).

Market orientation primarily focuses on securing a permanent inflow of work and realising a profit for the company by satisfying the demands and needs of clients. Although a lot has recently been said about the need for marketing in the construction industry, the great majority of companies has unfortunately remained on the level of declarations.

Present conditions in the Croatian construction industry are bad, as the result both of "transition illnesses" and the strong impact of the almost five-year-long defence war whose effects are still present in all segments of the economy. This motivated the authors to conduct an empirical study aimed at assessing the level of marketing in the Croatian construction industry.

This paper should be taken as a modest contribution to the sum of existing knowledge about the complex field of construction in a country in transition.

WHY CROATIAN CONSTRUCTION COMPANIES DO NOT USE MARKETING?

The answer may lie, on one hand, in the specific role of the construction industry in national economies.

For decades after the Second World War the construction industry in what was then Yugoslavia was strongly engaged in the reconstruction of the war-torn country (as was the case in most European countries) and the only investor of any importance was the state. Private ownership did not exist because all private property in Yugoslavia was nationalised after the Second World War.

Another factor is that for fifty years people lived and worked in a socialist economy and that the socialist way of thinking, where "the state takes care of the needs of its citizens", cannot easily be erased from people's "heads". We must not forget that Yugoslavia had a planned economy right until the end of the 60s, and even after that, although a market economy existed on the declaratory level, it still remained under the very strong influence and control of the state.

Right until the end of the 70s the construction industry was part of very intensive capital investment where the state was usually the investor. In that entire period the demand for construction was greater than its supply. The logical effect were "spoilt" companies that did not have to do very much to find work and make a profit because the state supplied enough work for all, and socialism did not recognise the category of profit in any case. One of the essential elements for the functioning of the system of socialist self-management was full employment, and large construction companies at that time employed up to 5 or 8 thousand people.

In the early 80s the entire developed world went into a recession that did not bypass Yugoslavia, either. This led to a considerable decrease of investment, and companies started to face a crisis in the demand for construction work. The idea of a marketing orientation and the need for market research began to "shyly" appear and be mentioned in the Yugoslav construction industry, too, and some construction companies began to behave according to the rules of the market economy, primarily by taking heed of customer demands.

However, in 1991 Croatia was attacked and a war began which lasted for almost five years. The war and the ensuing devastation left the state and the population greatly impoverished.

As a direct consequence of the destruction of factories, hospitals, schools and the entire infrastructure of towns, the exceptionally great "costs of the war", many companies failed and people lost their jobs. Today the Republic of Croatia has 350,000 unemployed, which is almost 20% of the work-capable population, and in 1998 the GNP per person was US$4,462, which is 84% of the GNP in 1990.(Ministry of the Environment..., 1999).

This resulted in decreased investment (and it is known that about 50% of any investment is taken up by construction), in a great decrease of the value of construction and, of course, a decease of the number of people employed in the construction industry in the last ten years.

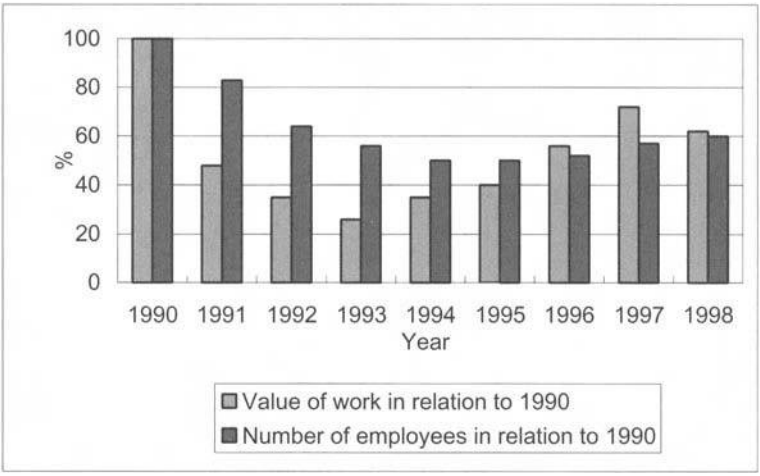

Figure 1 Changes in the number of employees and value of performed work in the 1990-1999 period

The value of work in 1999 fell by 46% in relation to 1990, while the number of workers in the same period fell by 40%.

A rough estimate shows that today state participation on the investment market is 40%, while the usual participation in developed western countries is between 40% and 50% (Đukan, 2000).

Reconstruction began as soon as the war ended. The state was again the most important investor, financing most of the reconstruction in the war ravaged country. From about the second half of 1992 to the middle of 2001, the Republic of Croatia invested over US$1.3 billion in reconstruction, thereby renewing 94,907 housing units (Ministry of Reconstruction, 2001).

Reconstruction took place through several different models.

Reconstruction organised through the Ministry of Reconstruction included:

- 32,100 houses of 4th-6th category of damage, to the value of US$1 billion,
- 3,920 houses of 1st-3rd category of damage, to the value of US$ 32 million,
- 2,105 flats in high-rises, to the value of US$ 30 million,
- 12,861 houses renewed with the financial support of the Ministry,

- 5,800 houses renewed with the support of the Ministry in construction material.

For another 42,800 family houses, which were less badly damaged, the Republic of Croatia ensured favourable bank loans for self-renewal to a value of US$ 236 million.

In addition, the Republic of Croatia renewed through the Ministry 27 churches and monasteries to the value of US$5,6 million, and 152 schools to the value of US$ 31,5 million.

However, the state cannot ensure enough work for all, and it is completely clear that the Croatian construction industry is in a very difficult situation. It is high time for construction companies to begin to systematically operate according to the principles of the modern market economy, i.e. to at least begin thinking about the need for a marketing approach in construction so as to ensure the inflow of work and profit. Of course, not on the declarative level, but to truly accept a business philosophy that places foremost the market and customers, their wishes and needs.

ANALYSIS OF THE USE OF MARKETING IN SELECTED CONSTRUCTION COMPANIES

For the needs of this paper we conducted a small investigation to discover the actual "conditions in marketing" and the main reasons why Croatian construction companies do not use the "marketing philosophy". We wanted to learn about the stands and approach to marketing and its use of the key people in construction companies.

In 2000 there was a total of 5,067 construction companies in the Republic of Croatia, with 70,522 employees. There were only 38 (0.75% of the total number) "large" companies (with over 250 workers), but these employed 25.67% of all employees and made 31.36% of all the income in the construction industry in the Republic of Croatia.

There were 4,834 (95.4%) "small" companies (with less than 50 workers). These employed 51.17% of the total number of employees and made 43.03% of all the income in the construction industry in the Republic of Croatia (Institute..., 2001).

Therefore, we decided to conduct a survey among 7 of the largest construction companies, which in 2000 employed 9,900 workers (14% of the total number of workers) and made an income of US$ 380 million (13,2% of the total income).

Our reasoning was that "large" companies are as a rule the bearers of development and the seedbed of new ideas, and that they should be the first to adopt new ideas and apply new business methods.

The questionnaire had a small number of questions and we got very interesting results.

1. Is there a marketing service in your company?

   - Four companies had a marketing sector, three did not because the management considered that they do not need marketing.

   - ***Only four respondents answered questions 2-6 (those that gave a positive answer to the first question), which referred to the position and activities of marketing in the company.***

   - The four companies had a very different understanding of marketing. In some the marketing sector also included technology design, offering and contracting work, and planning. In another the marketing sector included promotion, public relations and market research.

   - The number of employees depended on the volume of work of the marketing sector and ranged from1-49 employees, of very different professional profile (psychologists, economists, construction engineers).

7. How does the company promote its activities?

   - All the respondents (7) used catalogues, brochures and participated at specialised fairs. Printed materials varied greatly in quality and modern design. Only one company used modern forms of promotion on www pages, which were very clear and of very high quality.

8. How do you usually secure work?

   - All the respondents (7) secured work through competitions but also through direct agreements (some more often than others).

9. How would you personally define the concept of marketing?

   - Four out of seven respondents did not answer (there is no marketing in those companies), two respondents answered that this is an "activity that includes promoting and placing products on the market according to the results of market research", and only one respondent said that "these are activities connected to the customer, his demands and needs – to which production must conform, along with satisfying the demands of quality, speed and price of construction".

What to conclude from these results? If this is the condition among the "large" companies, which have the personnel and financial potentials to invest in development, how do things stand in the "small" companies that cannot employ specialists and which are barely making ends meat.

It is a fact that many companies in developed economies are not market oriented, either. The reasons why firms are not always in close touch with their market environment include (Walker, 1996):

- Competitive conditions may enable a company to be successful in the short run without being particularly sensitive to customer needs and desires,

- Different levels of economic development across industries or countries may favour different business philosophies,

Firms can suffer from strategic inertia – the automatic continuation of strategies successful in the past, even through current market conditions are changing.

In our opinion, the main reason is inertia, not as a result of successful business strategies but as a result of the habit for "others" to solve problems and introduce changes.

In transition countries, including Croatia, people still think that the state is obliged to take measures. That is why we all expect the state to take measures to advance conditions in the construction industry, as if the Croatian economy was not a market economy like that in all other developed European countries. Yes but old habits die hard.

The state may and must act to change the general conditions of doing business in a country, which are anything but balanced in Croatia, but true changes in business operation and in relation to the market and the customer must take place on the company level, in the consciousness of managers and all employees.

In his article "The rediscovery of the marketing concept" (Webster, 1988) claims: "Marketing is not something that could be delegated to the small group of managers, while the rest of the company does its 'own' job. Rather, it is all business seen from the customer perspective" Truly accepting marketing behaviour in a company implies knowing all the relevant facts connected with the market. More precisely, this means knowing:

- The existing, potential and the former market,

- The company's production strength, weaknesses and advantages and comparative advantages and development potentials,

- The environment (social and economic aspects in the environment in which the company is working or would like to work).

Construction companies must organise their marketing in the stage of planning business activities for a specific period, and through defining customer needs and demands, and new business opportunities.

It is essential to bear in mind that the marketing philosophy insists on the following order – satisfy the customer/investor and at the same time make a profit.

The customer always comes first... Emphasis is on establishing good relations with the client throughout the entire realisation of the common project. Good cooperation between the company and investor is indispensable if a project is to be successful, because helping the clients to explore their requirements, and then ensuring that those requirements are met, are crucial to project success. Good relations with a client lead to repeated business and referrals.

CONCLUSION

The analysis of conditions in the construction industry in the Republic of Croatia, which we briefly presented in this paper, indicates a very difficult and complex situation characterised by a high supply and small demand on the market. However, although confronted with the great problem of finding work, many companies have still not, for many objective reasons but also because of subjective organisational weaknesses, changed their approach to the market and the customer. For example, it is still very difficult to produce a product of "perfectly quality", at an acceptable price and in the agreed term (delivery within the client's required time frame is an important part of the company's market orientation).

The questionnaire, whose conclusions must be regarded as tentative because of the small number of selected respondents, indicates the disturbing fact that, although we have already stepped into the 21st century, Croatian construction companies have still not seriously grappled with market demands and broken off with work and business operations usual in the socialist economy.

Even the largest companies do not have a developed market approach, and they are expected to be the leaders of development (in every case). It is very difficult to be certain whether the reason for this is lack of knowledge or lack of a will to change. Probably both.

In any case, this kind of behaviour does not promise the company prosperity, because only the best and the most capable succeed on the market. The others fail sooner or later.

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Bidding Strategies in Japanese Construction Projects

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BACKGROUNDS AND PURPOSE OF RESEARCH

The Central Council on Construction Business, Ministry of Construction[1] (MOC) submitted "The Reformation of bid and contract system for public works" on Dec. 21st, 93. It became the turning point of the bid and contract procedure and management for public works, which had been used for along pre-post war period. The consideration for improvement of these systems has started since then. "The aim of construction industry corresponding to the changing system of construction market" on Feb 4th, 98, made a suggestion of an introduction of various bid contract systems such as VE (Value Engineering) and DB (Design Build) and the publication of the estimated price to pursue the transparency of the system.

Due to those suggestions, the local government and the Regional Construction Bureau, MOC have provided the information about bid result to the public recently. Table 1 shows the trend of "transparency" of local public organizations, according to the research by Ministry of Construction. The tendency of system reformation by each local government can be seen in Table 1.

The main information that should be opened to the public are "name of the construction project", "successful bidder", "successful bidding price", "list of whole bidders", "their bidding price" and "estimated price". The information is provided to public on each web site.

The purpose of this research is analysing the provided bidding information backed by this reformation. To be concrete, it is expected that the characteristics of the bidding behaviour would be shown eventually by examining the bidding result provided on the web site, using the statistical analysis.

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[1] "The Ministry of Construction" became a part of "the Ministry of Land, Infrastructure and Transport" in January, 2001. However, the name of reflecting when the object data is collected is used in this research.

DIVERSE DEVELOPMENT OF BIDDING STRATEGY RESEARCH IN FOREIGN COUNTRIES

Both Europe and the U.S. have plenty of researches about bidding strategy from the wide range of study field. There are some well-known places for the presentation of the article on construction bidding. CIB W-55 (Building Economics) and W-65 (Organization and Management of Construction) are known as international research organizations on Construction field, and "Building Economics and Management" edited by University of Reading, UK, and ASCE magazine, U.S. are also typical magazine for this kind of research.

As well as Construction field, the researches on the bidding strategy have been done in Economics and Operations Research (OR) fields.

The first definite article on bidding strategy was " a competitive bidding strategy" by Laurence Friedman (1956) specializing in OR at Case Institute of Technology. The article showed a model for competitive bidding strategy model. According to R. de Neufville (1991), MIT, U.S., with the model, the strategy for maximizing the bidders' bidding expectation, as a start, other models (i.e. calculating the successful bidding possibilities by different way, dealing with not profit but cost as a random variable) were

Table 1 Trend of "Transparency" of Local Government in Construction Procurement in Japan. (unit: %)

	Prefecture (47)			Government ordinance designated city (12)			Cities,towns and villages (approximately 3,240)		
	FY1999	1998	1997	FY1999	1998	1997	FY1999	1998	1997
Introduction of high bid method of transparent nature/competition nature*1	93.6	89.4	87.2	83.3	75.0	75.0	10.3	7.7	6.5
Announcement of nomination standard*2	95.7	95.7	95.7	100.0	100.0	100.0	46.7	46.1	34.5
Announcement of nomination merchant*3	87.2	95.7	100.0	75.0	91.7	91.7	58.7	65.6	65.2
Announcement of bid result*2	100.0	100.0	100.0	100.0	100.0	100.0	87.6	85.6	83.1
Announcement of order standard*2	95.7	95.7	–	100.0	91.7	–	31.9	29.5	–
Establishment of nomination examination committee *2	100.0	100.0	100.0	91.7	91.7	91.7	93.6	93.5	93.3

Abolition (all the abolition) of construction work completion surety	95.7	95.7	93.6	91.7	91.7	91.7	78.5	74.6	57.3
Plan of negotiation information correspondence manual[*2]	87.2	87.2	87.2	91.7	75.0	75.0	35.2	30.6	23.0
Introduction of the low bid price survey system	93.6	91.5	—	100.0	100.0	—	6.6	2.8	—
Announcement of estimated price after bid	95.7	59.6	—	100.0	66.7	—	20.9	6.3	—
Announcement of estimated price before bid	14.9	—	—	41.7	—	—	1.9	—	—
Announcement of qualification merchant grade	42.6	21.3	—	41.7	33.3	—	6.0	5.3	—
Elimination of defective unsuitable merchant (the CORINS[*5] registration)	100.0	100.0	—	100.0	100.0	—	22.5	21.5	—

Source: Ministry of Construction

Notes 1: This shows achievement of the introduction in public offering style nomination competition bid.

2: This is the number with regard to general civil engineering work.

3: The fiscal year 1999 survey focuses on the parties that announced the nomination merchant name "before bid ".

4: The number summarizing the survey result that is divided into the cities, towns and villages calculates the numerical value in 1997 fiscal year survey.

5: CORINS: Construction Records Information Service, operated by JACIC (Japan Construction Information Center: Semi-government foundation).

developed afterwards. (Willenbrock (1973), de Neufville et al. (1977), Ibbs and Crandall (1982), etc.) These models could explain not only the number of bidders competing with each other but also dynamics of complicated bidding process. In these researches, demonstrative analysis, like investigation of the factors making influence on the contractors at the time of bidding, has also been done.

Also in economics field, there are bunch of analysis both theoretically and practically, such as applying the game theory to calculate the exceeding profit in Construction Bid Rigging (McMillan (1991)) and making an experiment on bid Rigging in the laboratory (Artale (1997), Une&Saijo (1995)).

AASHTO, U.S., has been taking advantage of BAMS by computer since 1985, and one of the modules of this system, BAMS/DSS enables us to collect and analyze detailed data on purpose of checking the regional misdistributions of orders, validity of estimate by Construction firm and collusive behavior among contactors.[2]

In short, though the bidding strategy matter has offered an active argument both academically and practically in Europe and the U.S., it was harder object to be researched in Japan contrary to the tendency of Europe and the U.S.[3]

POINT OF VIEW ABOUT THIS RESEARCH

In this research, we statistically analyze the data obtained in Japan using the knowledge or analyzing skill from the result of bidding researches in Europe and the U.S. The point of view about this research is roughly grasping the bidding action of Japanese contractors, but there are two ways used for this analyze, that is, 1) analyzing by focusing on each individual bidding and 2) analyzing by focusing on each individual contractor.

Through 1), the situation of competitions, correspondent to the types of work and ordering organization, would be expected to be understood from the number of bidders, successful bidding percentage and bidding price distribution. Through 2), it is possible to analyze the pattern of bidding behavior by defining each contractor's competitiveness.

OUTLINE OF THE PROVIDED BIDDING DATA

This research utilizes about 4000 construction firms' bidding data on 398 bidding construction projects by the Local Construction Bureau, MOC, obtained on the web site. Table 2 is for each type of Local government and construction held around Jan to Mar in 1999. The total price for 398 construction projects is 210,397,000,000 yen (528,600,000 yen per one on the average, which is relatively high) and this is equivalent to 20 percent of total order price (1,154,841,000,000 yen) during this period.

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[2] Detailed analysis models are prepared for Inspector general's office. For instance, as follows: define economic markets, market share analysis, vendor competition analysis, contract analysis, pricing analysis, contract modification analysis. Each analysis has several models. However, details of the analysis method are not open to the public.

[3] The field of the law study was researched concerning the bid system of the construction project of Japan though the number was little. The research of the bid system has been published in the field of experiment economics and the Civil Engineering recently. Moreover, the bid data is analyzed by the citizens ombudsman etc. though it is not a science field.

The information that we could obtain on the web site is name of the bidding project, order classification –Building works, Civil engineering works, Equipment works and others: the classification used here is divided up by the author – client division, bidding date, the number of times for bidding [4], estimated price, bidder's name, successful bidder`s name and successful bid price.

This kind of data is required to obtain continually as they will not be provided on the web site for a long period and it'll become harder to obtain the data after certain period.

Table 2 Outline of Data for the Analysis (Bid Object Issue)

The Regional Construction Bureau, Ministry of Construction	Period*1	Number of bids in terms of order classification (type of work)				Total
		Building works	Civil Engineering Works	Equipment works	Misc.	
Tohoku	1998.7.23～98.8.6	4	0	1	0	5
Kanto	1999.1.8～99.3.17	12	109	23	30	174
Chubu	1999.1.21～99.3.10	5	56	15	0	76
Kinki	1999.1.7～99.2.18	2	3	7	0	12
Chugoku	1998.2.03～99.3.16	20	83	28	0	131
Total	—	43	251	74	30	398

Notes: Only the data shown in each district construction office HP in April in 1999 are analyzed above.

1.The bid day is shown.

COMPETITIVE SITUATION OF BIDDING

Number of Bidders

Bidding is to be competed among some bidders, and the average number of bidders is 9.18 (See Figure 1). The maximum number of bidders is 20 and the minimum is 1 (this is supposedly voluntary contract). The most popular case is competition among 10, and this might be because the regulation specifics, "The competition must be participated in by at least 10 person." F-value based on variance analysis among the Regional Construction Bureau is 13.14 (degree of

[4] When the lowest price exceeds the estimated price, the re-bid is done. The re-bid is usually done up to three times including the first bid, and becomes a voluntary contract with those who present the lowest price still when not deciding. In this case, the bid value of each company up to three times is indicated in the home page.

freedom: (4, 393)), comparatively high, and the conclusion reaches that the average number of competitors is different depending on the Regional Construction Bureau.

Table 3 Mean Value of Number of Bidders.

Name of the Breau	Mean	Max	Min	Standard deviation	Sample size
Tohoku	8.20	10	5	2.17	5
Kanto	8.29	16	1	2.63	174
Chubu	10.12	13	3	1.56	76
Kinki	9.33	12	6	1.78	12
Chugoku	9.85	20	3	2.09	131
Mean	9.18	20	1	2.39	398
Variance analysis	Degree of freedom(4, 393), F=13.14, p=0.00%				

Type of work	Mean	Max	Min	Standard deviation	Sample size
Building works	9.63	16	3	2.31	43
Civil EngineeringWorks	9.37	20	1	2.33	251
Equipment works	8.72	12	3	2.28	74
Misc.	8.10	11	2	2.82	30
Mean	9.18	20	1	2.39	398
Variance analysis	Degree of freedom(3, 394), F=4.13, p=0.007%				

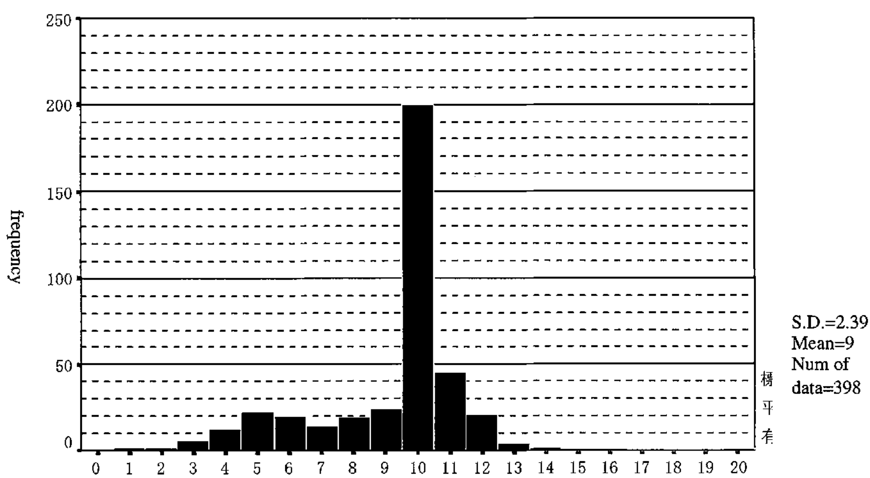


Figure 1 Histogram of number of bidders (all the data)

Successful Bidding Rate

"Successful Bidding rate" means the percentage of bidding price to estimated price. The average rate is 97.13% (See Figure 2.). Obvious gap cannot be recognized among the Regional Construction Bureau due to the variance analysis, but F-value for each type of work is 12.51 (degree of freedom: (3, 378)), kind of high, and a competition state is different from each type of work. (See Table 4.) Average of 'building works' is relatively small and standard deviation is large, and compared to it, average of 'civil engineering works' and 'equipment works' are large and the deviation is small.

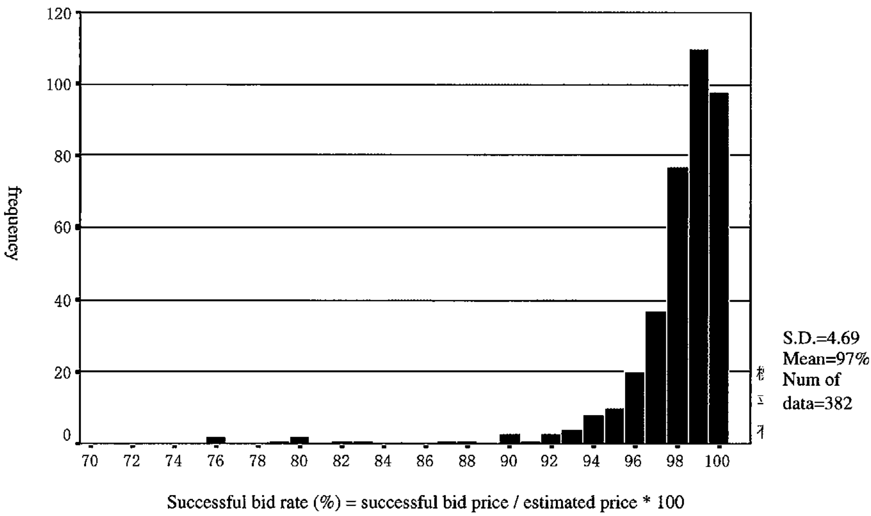


Figure 2 Histogram of successful bid rate (all the data)

Table 4 Mean Value of Successful Bid Rate

Name of the Breau	Mean	Max	Min	Standard deviation	Sample size
Tohoku	96.83	97.54	95.91	0.69	4
Kanto	97.59	99.93	75.78	2.91	173
Chubu	97.22	99.59	79.47	2.84	76
Kinki	96.40	99.47	78.59	5.82	12
Chugoku	96.49	99.84	48.78	7.10	117
Mean	97.13	99.93	48.78	4.69	382
Variance analysis	Degree of freedom (4, 377), F=1.04, p=0.39%				

Type of work	Mean	Max	Min	Standard deviation	Sample size
Building works	93.27	99.64	51.51	9.48	40
Civil Engineering Works	97.77	99.93	48.78	3.65	240
Equipment works	96.66	99.84	79.47	3.50	73
Misc.	98.36	99.88	95.56	1.19	29
Mean	97.13	99.93	48.78	4.69	382
Variance analysis	Degree of freedom (3, 378), F=12.51, p=0.00%				

DISTRIBUTION OF BID PRICE

Coefficient Variation of Bid Price

The standard deviation is considered as measurement of dispersion among bid prices, however it is easily influenced by the construction project size, and not proper for comparison. Coefficient of Variation, distribution of the value that is divided by average bid price, is used as a comparison measurement. This is defined as Coefficient of Variation = Standard deviation / average value.

The histogram for 395 data made by means of Coefficient of Variation is Figure 3. and the whole average is 2.9%. Citing the data by Skitmore (1988), the data of Europe and the U.S. (Table 5). We can see that they are in the range of 5-8.4 %. The difference of the bid price is few as long as in this data compared with a general data of Europe and the U.S.

Figure 4. shows that the varying level of Coefficient Variation due to types of work and the Regional Construction Bureau of orders. Figure 4. (next page) is called "Box-and-whisker plots", indicating Median and Quartile point, half of the cases can be put in the box. (The line shown in the box is Median.) [5]

[5] The sign " O " shows the data 1.5 times or more the length of the box away from a top and bottom of the box edge. The sign " * " shows the data 3.0 times or more away. An upper and lower moustache indicates maximums and minimum observation data except the coming off price.

Table 5 The Parameter of the Bid Price Distribution (the paper survey by Skitmore)

	Modeller / Location	Year	Shape	Spread
No. 1	AICBOR (3) a	1967		cv 6.8%
No. 2	Alexander (1) d	1970	Normal	
No. 3	Arps (2) d	1965	Lognormal	
No. 4	Barnes (4) m	1971	(unknown)	cv 6.5%
No. 5	Beeston (5) i	1974	Pos. skewed	cv 5.2-6%
No. 6	Brown (7) d	1966	Lognormal	
No. 7	Capen et al. (8) d	1971	Lognormal	
No. 8	Cauwelaert & Heynig (9) a	1978	Uniform	
No. 9	Cauwelaert & Heynig (9) g	1978	Normal	
No.10	Crawford (10) a	1970	Lognormal	
No.11	Duogherty & Nozaki (11) d	1975	Gamma	
No.12	Emond (12) d	1971	Normal	
No.13	Fine & Hackemar (13) b	1970	Uniform	cv 5%
No.14	Friedman (14) a	1956	Gamma	
No.15	Grinyer & Whittaker (15) c	1973	Uniform	cv 6.04%
No.16	Hossein (16) k	1977	Gamma	
No.17	Klein (18) d	1976	Lognormal	
No.18	McCaffer (19) f	1976	Normal	cv 6.5%
No.19	McCaffer (19) n	1976	Normal	cv 7.5%
No.20	McCaffer (19) j	1976	Normal	cv 8.4%
No.21	McCaffer & Pettit (20) d	1976	Pos. skewed	cv 8.4%
No.22	Mitchell (21) a	1977	Normal	
No.23	Morrison & Stevens (23) m	1980	Normal	19.1% av. range
No.24	Oren & Rothkopf (24) a	1975	Weibull	
No.25	Park (25) h	1966	Pos. skewed	
No.26	Pelto (26) d	1971	Lognormal	
No.27	Shaffer & Micheau (28) p	1971		cv 7.65%
No.28	Weverberg (33) a	1982	Lognormal	
No.29	Whittaker (34) c	1970	Uniform	1.068

Notes: 1. Source: Martin Skitmore (1988) "the distribution of construction project bids." *CIB W-55*, pp.171-183.

2. The numerical number in the blacket at the 'Modeller' above shows the reference papers number in Skitmore (1988).

3. Means of alphabet at the 'Modeller' are as follows:

a □Theoretical assumption
b □Analysis of an 'adequate' sample of UK construction projects
c □Analysis of 153 UK government construction projects
d □Oil and mineral tracts in USA – unknown source of data
e □Assumed for simulation studies
f □Analysis of 183 Belgian building projects
g □"consistent with work of other researchers"
h □construction projects in USA –unknown source of data
i □Large sample of PSA projects
j □Analysis of 384 Belgian roads contracts
k □Analysis of 545 US civil engineering and 63 mechanical engineering projects
m □Analysis of 159 UK construction projects
n □Analysis of 16 Belgian bridges projects

o □Analysis of 213 UK motorway projects
p □Analysis of 50 USA construction projects

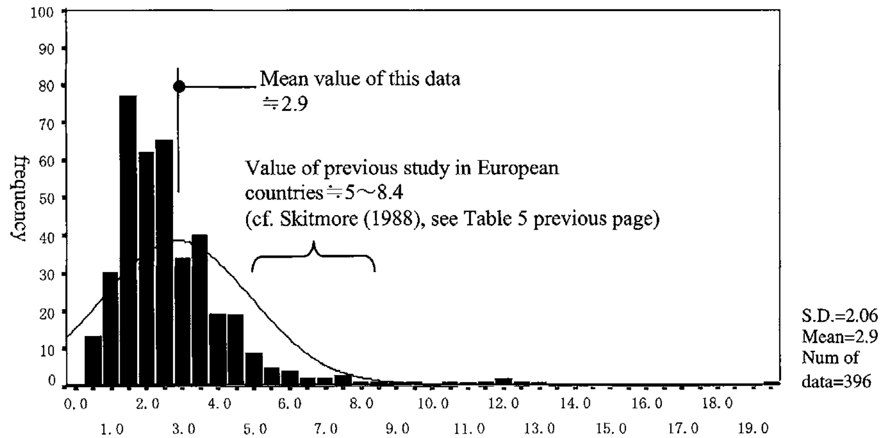
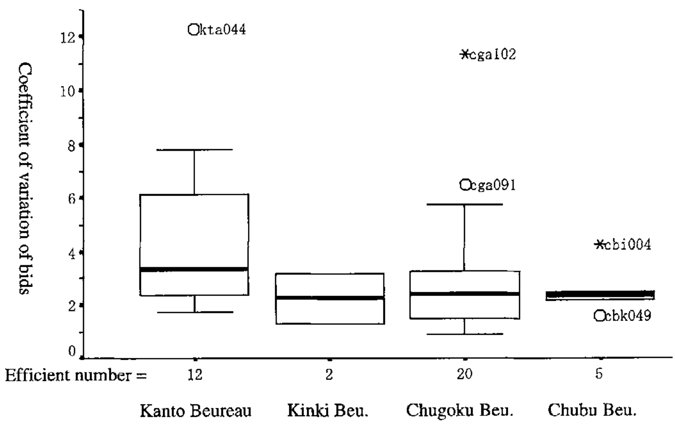
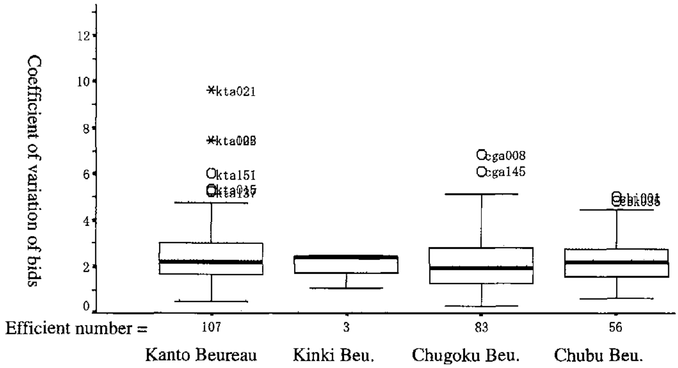


Figure 3 Histogram of coefficient of variation of bid price.

(1) Building works



(2) Civil engineering works



(3) Equipment works

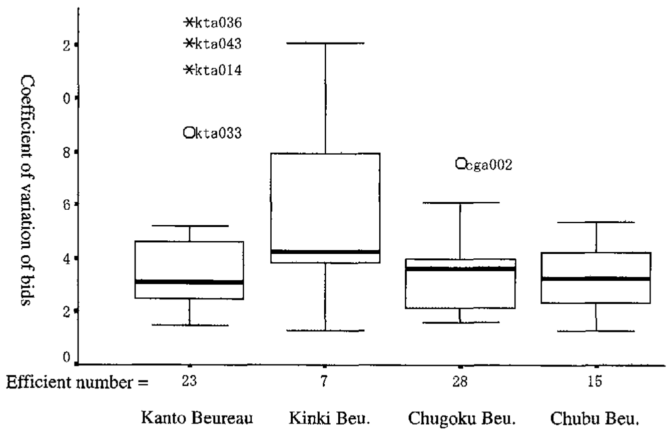


Figure 4 Distribution of coefficient of variation of bid price.

Generalizing is impossible because there is gap among samples, but the obvious tendency we can see is 'equipment works' have big dispersion and seeing from each Regional Construction Bureau, the Construction of Kanto Bureau and 'equipment works' of Kinki Bureau especially have wide dispersion. The variance analysis of Coefficient of Variation average using the 366 data, limited to 3 types of work (building works, civil engineering works and equipment works), shows that 18.602 of F-value (degree of freedom:(2,363)) for each Regional Construction Bureau and 2.613 of F-value (degree of freedom: (4,361)) for each type of work. The dispersion is different from each other both for type of work and the Regional Construction Bureau.

Kurtosis and Skewness of Bidding Price Distribution

Skitmore has researched 29 cases to figure out bidding price distribution forms, and "Normal Distribution" (9), "Log Normal Distribution" (7), "Uniform Distribution" (4), "Gamma Distribution" (3), "Asymmetrical Distribution" (3) and others (3) is shown as a result.(See Table 5.) It is also said that the cases of typical competitive bid have symmetric form. (Beeston (1983))

Focusing upon Kurtosis and skewness to sum up the huge data, we could see that the larger has sharp Kurtosis and the smaller has gentle one when setting 3 as standard. The standard of skewness is 0 because with the symmetrical pattern, and the larger has left-bent distribution and the smaller has right-bent distribution. Figure 5 is the scatter diagram plotting Kurtosis and skewness of 384 bidding price data. Its form looks U of alphabet. The average of all is –0.315 Kurtosis and –0.178 skewness, and the overall form is flat and a shade right-bent. (See the area concentrating the points in Figure 5.)

Figure 6 is the histogram describing the typical parts of Figure 5. These 4 types are named unofficially in accordance with their distribution forms[6]. Analyzing from Figure 5 and 6, it is easily imagined that (2) and (4) are major types of bid.

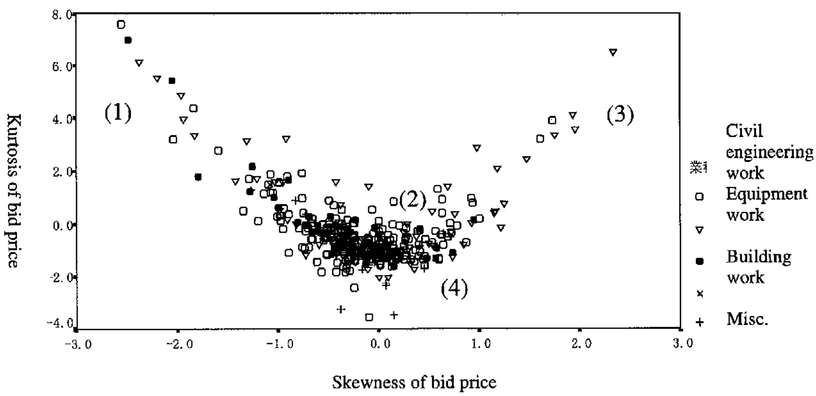


Figure 5 Kurtosis and Skewness degree of bid price distribution (scatter diagram)

[6] Four data shown here is the one having shown as a typical case to be distributed the bid price for the understanding of Figure 5. Therefore, it is not the one having aimed at making to the pattern through a strict procedure. This analysis is not the one having converted the distribution by which the bid price of each company into the standard distribution.

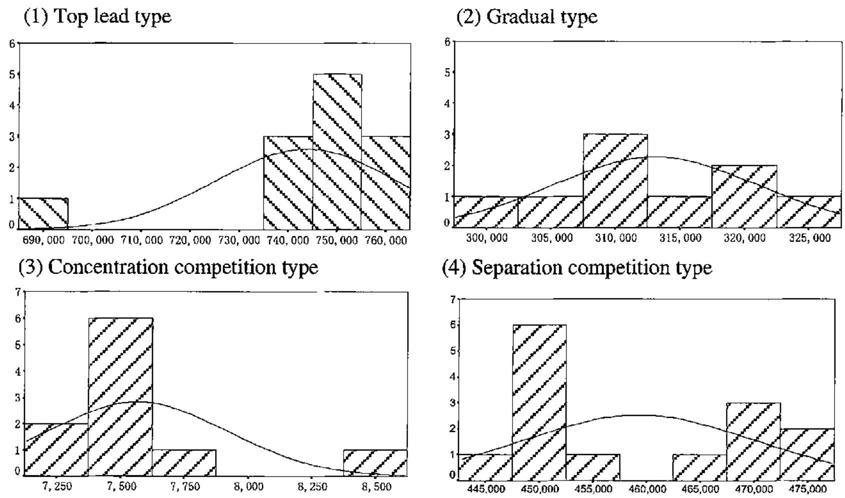


Figure 6 Typical examples of bid price distribution (Histogram of bid price, cf. Figure 5.)

The result of variance analysis with means of kurtosis and skewness for each type of work and every Regional Construction Bureau is shown in Table 6. As may be seen from this table, both types of work and construction have difference in kurtosis. On the contrary, not obvious difference is recognized for each type of work and is not recognized for each Bereau.

Table 6 Distribution Analysis of Mean Value Regarding Kurtosis and Skewness of Bid Price Distribution.

Name of Bureau	Mean value of kurtosis		Mean value of skewness	
Tohoku	0.267	(5)	-0.422	(5)
Kanto	-0.491	(162)	-0.159	(168)
Chubu	-0.359	(75)	-0.156	(76)
Kinki	1.546	(12)	-0.300	(12)
Chugoku	-0.265	(130)	-0.195	(131)
Mean	-0.315	(384)	-0.178	(392)
Degree of freedom	df(4,379)		df(4,387)	
F-value	6.167		0.353	
p-value	0.000		0.842	

Type of work	Mean value of kurtosis		Mean value of skewness	
Building works	0.007	(41)	-0.363	(43)
Civil EngineeringWorks	-0.516	(243)	-0.186	(246)
Equipment works	0.411	(73)	-0.035	(74)
Misc.	-0.958	(27)	-0.199	(29)
Mean	-0.315	(384)	-0.178	(392)
Degree of freedom	df(3,380)		df(3,388)	
F-value	9.100		2.223	
p-value	0.000		0.066	

Notes: the numbers inside of Brackets are an effective numbers.

COMPETITIVENESS OF BIDDERS

Let us change the focus from the distribution of bid data into bidders themselves. The estrangement level between some bidder's bid price and successful bid price shows the bidder's competitiveness in each bid. I collected the value data showing competitiveness of each and analyzed the bidder's entire competitiveness from that data.

The typical indexes defined with respect to the relationship with successful bid price are below:

1. bid price / successful bid price *100

2. {(bid price – successful bid price) / successful bid price}*100

3. {(company's proposed price - successful bid price) / successful bid price }*100

4. successful bid price / estimated price *100

No. 4, called successful bid rate, gets known from the activity of civil ombudsmen, but it has nothing to do with the bidder's competitiveness that we are going to explain here[7]. No.3, company's proposed price, cannot be shown here since it is treated as company secret, but can be an index to analyze the bidder's behavior principle when comparing with No.2.

The indexes No.1 and No.2 are the competitiveness value, which can be calculated by the information on the web site.

With regards to No.2, the book of Drew and Skitmore (1993) is available for reference. In this book, the authors are calculating the average value and standard deviation of each competitiveness value and classifying the bidder behavior with that data.

In the research, 238 bid price data of civil engineering works (i.e. harbor, highway, sewerage, site planning, aqueduct during 1991 to 1998 are utilized, and taking up 21 bidders who have an experience of successful bid over once and less than 5 times. When we set each average value as origin, the names of 4 quadrants are below:

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[7] The successful bid rate is an index to put the saving of the efficiency improvement of the administration, that is, tax on the mind entirely. The official rank in charge of the contract decides the lowest limitation price (low bid price investigation) for the construction project in the national project within the range of 67%-85% of the estimated price according to regulations of the law of accounting.

(a) "sensible type" with competitiveness and without scattering

(b) "non-serious type" without competitiveness and scattering

(c) "suicidal type" with competitiveness and scattering

(d) "silly type" without competitiveness and with scattering

We analyzed our data with the formula above. We obtained the bidding data over 5 times, and 118 bidders had an experience of successful bid over once[8]. The number of bid is no less than 1486. Figure 7 shows plotting data for average competitiveness and standard deviation defined in No.2. It is clear from this Figure that there is difference among behaviors toward presentation of bid price. We can see (a) "sensible type" and (d) "silly type" are superior as well as in the case in Hong Kong. However, the difference being caused by the type of work, it is required to limit the type of work to proceed analyzing.

The impressive result is the average competitiveness value of 118 bidders is just 4.24 and the standard deviation is 4.33, all of which are totally small when comparing with the data in Hong Kong (14.13 and 13.79 each). Almost all of the data indicated by bidders in Japan should be classified as "sensible type" in comparison with data in Hong Kong.

This fact shows that the behavior toward bid between Japan and Hong Kong are to a high degree different from each other. We could imagine some reasons for this difference, such as the superiority of "sensible type" bidders toward the presentation of bid price in Japan, the difference of bid system, sign of less competitive bid behavior, etc, but the reason we can testify with the data is so limited that the reason for this difference is not yet touched here. The continuous study is necessary.

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[8] When paying attention to the calculation process of competitiveness of an indivigual company, it is thought that the degree of the variance of the bid price has the decreasing tendency when the the re-bid exists in the same project . Having made a successful bid by the first biding among 118 companies and 1486 data used at this time occupies 1364 data(91.8%). The second time 121(8.1%) and the 3rd 1(0.1%). The analysis at this time includes all these data. It is thought that the comparison with this data and the Hong Kong data which seems that the goverment does not bid again by the same project is appropriate.

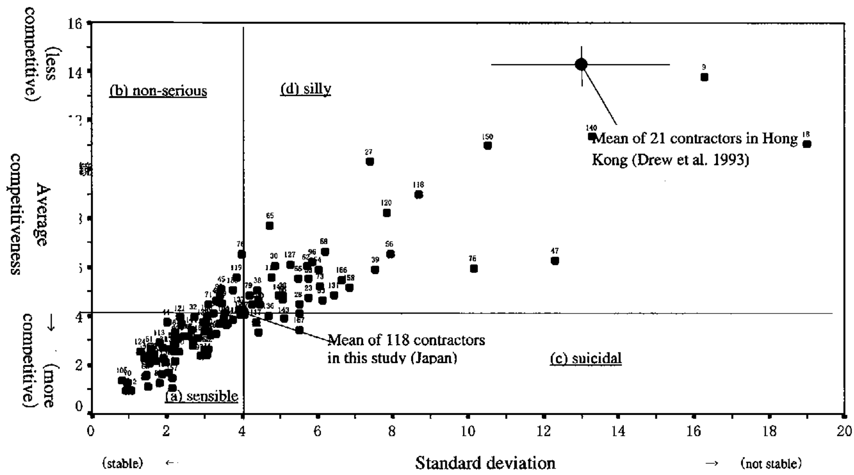

Figure 7 Classification of Japanese construction enterprises.

Notes: 118 companies which bid at least 5 times and have successful bids once or more.

Table 7 Competitiveness Value and Standard Deviation (Mean Value in Terms of Work Type)

Type of work	Mean of competitiveness value	Stanadrd deviation	Sample size
Building works	6.63	7.14	105
Civil EngineeringWorks	3.49	4.89	1,076
Equipment works	7.02	7.85	179
Misc.	4.04	4.46	126
Mean	4.18	5.63	1,486
Variance analysis	Degree of freedom(3, 1428), F=28.75, p=0.000%		

Notes: It depends on the bid data sampling 118 companies showed in Figure 7.

CONCLUSION

We have analyzed the bid data opened to public, using the index or the analysing method shown by leading researches, to deepen our understanding of bidder's behavior. We hope that continuous analysis will help our understanding of bidding strategy in the building project.

To reiterate the results written in it, they are as follows:

-- The bid has been competed among more or less 10 bidders for the construction projects ordered by MOC. The average number of bid participants doesn't have difference by the type of work, but have by the type of the Regional Construction Bureau, MOC. On the other hand, the successful bid rate (97.13% on the average) have difference not by the type of locality (i.e. the Regional Construction Bureau, MOC) but by the type work.

-- The case study in Europe and the U.S. shows that Coefficient of variation for each bid is between 5-8.4% (this data is a little bit old), but the analyzing data shows 2.9%, smaller than the percentage above. Checking over the percentage of the case in Japan, even though some gap is recognized in the data for each type of work and each Regional Construction Bureau, MOC. But the scope of scattering of overall value is not wide, compared with that of Europe and the US.

-- The experiment collecting and analyzing the bid data for each building companies shows the same result as above. The company taking a "sensible type" of bid behavior is a mainstream in Japan compared with the case in Hong Kong. "Sensible type" enables the bidders to present the price, which is closer to the successful bid price.

-- The reason of this bid behavior can be imagined some, but we have still looked for the appropriate reason. The bid rule particular in Japan, like Price Limitation System, and the difference of market environment can be considered as the reasons, but the clear reason is not known yet.

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PUBLIC-PRIVATE PARTNESHIP DELIVERY SYSTEMS FOR MUNICIPAL INFRASTRUCTURE PROJECTS: THE MANAGEMENT CAPACITY ISSUE

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ABSTRACT

*With the end of the apartheid era, the South African government began investigating a variety of innovative approaches to municipal (local government) service delivery that many other countries had refined and tested during the long period of South Africa's international isolation. Often grouped together as '**public-private partnerships (PPPs)**' – also referred to as municipal service partnerships (MSPs) to include possibilities for public-private partnerships – these approaches include long-term concession and lease contracts, management and service contracts, as well as outright sales of government assets. Local authorities as clients in these PPPs, and especially Local Authorities Departments of Public Works(LADPWs), need to maximise organisational effectiveness and be equipped in the understanding of dynamics attached to controlling demands of projects and making choices within constraints. Due to sophistication of projects delivery systems, LADPWs need to have personnel well conversant with allocation of* *budget and contingencies –* ***capable of managing the cost parameter****; adjustment of timing, time-scales and floats –* ***capable of managing the schedule (time) parameter****; adjustment of specifications (to basic, medium or high) –* ***capable of managing the quality parameter****; and making value judgements between higher initial costs and longer-term savings –* ***capable of managing the subsystem focussing on the utility parameter****. This paper focuses on the need to maximise organisational effectiveness and the importance of embracing "better practices" in dealing with issues of supervision and accountability in PPPs. It reports on the results of two investigations: conflict management diagnosis within LADPWs and an investigation into Total Quality Management (TQM) implementation and understanding in LADPWs. The Western Cape Province Local Authorities are used as a case study. The paper reports on* ***LADPW's perceptions about preferences of conflict management styles, intergroup and intragroup conflicts, diagnosis of conflict, TQM principles, commitment to implementing TQM, and beliefs about its effect relative to more "traditional" management philosophies****. It reports on* ***the LADPW' perceptions about organisational conflicts and obstacle(s) to successful TQM implementation;*** *it identifies measures that LADPW can use to improve organisational effectiveness and determine the success of TQM efforts; and finally recommendations and conclusions are made.*

INTRODUCTION

In 1998, after two years of preparation, the South African national government paved the way for public-private partnerships (PPPs) by creating the Municipal Infrastructure Investment Unit (MIIU), a non-profit company tasked with providing technical assistance and grant funding to municipalities investigating innovative service delivery partnerships. The long term aim of MIIU is to develop a market place in which informed local authority officials and professionals can obtain the services of private sector advisers, investors and service providers - as well as other public sector service providers and experts - to find more cost-effective ways of providing urban services to citizens.

Discussion with stakeholders in the government and the private sector, as well as analysis of policy and guidelines documents, procedures and international literature, have highlighted a number of constraints, opportunities and necessary conditions for PPPs in South Africa. For a greater number of PPPs to be implemented successfully, it is essential for these issues to be dealt with decisively: ***need for policy reform*** *- the need for cross-departmental policy coherence and consistency*; ***legal and procedural reform required*** *- the need for reform that would make the legal environment more PPP-friendly*; ***public finance issues*** *- the need for an appropriate framework to balance priorities between sectors and to ensure prudent control over the government's financial commitments*; ***capacity and training issues*** *-functional capacity to engage in partnership-type transactions*; and

***institutional arrangements** -a regulatory and support framework, which is driven and monitored by effective institutions.*

This paper focuses on one of the above issues: ***capacity and training issues***. The need for capacity and training is approached from Masterman's (1992) argument about experienced clients. According to Masterman (1992), experienced clients regularly carry out construction work and have little difficulty in obtaining information from, and dealing with, the construction industry as they will have developed a method of working, based upon past experience, which should enable a high level of success to be attained.

Although Municipal authorities seem to fit into the Masterman's (1992) definition of experienced clients, there are strong indications to suggest that they are facing capacity constraints in the sphere of project management – especially in their ability to understand the principles of project management, where there is better understanding of 'value for money' in their choices of infrastructure and service delivery options.

According to Rwelamila and Savile (1994) the client's objectives in the construction project are the achievement of **quality, cost, time, and utility.** Quality is the building level of conformance to specification, while cost relates to first cost or price of the building. Time is timing, or the completion of the project in accordance with the planned time. Whereas utility includes running costs, maintenance issues, buildability and flexibility for alterations or other uses (Rwelamila, *et al.* 1999).

The above four parameters present constraints and choices to the project management team, the balancing should, therefore, be struck to achieve them without compromising resources available on the project. Most of construction projects are procured based on only two of these objective parameters, namely: cost and time (Rwelamila, 1996). The optimum *utility* of a construction project can be obtained by making value judgements between higher initial costs and longer-term savings (Rwelamila, *et al.* 1994). Quality, one of the two focus areas of this paper, has been neglected (Rwelamila, 1996). According to Rounce (1998) the main attributes to the neglect of quality among others are; firstly, broken promises on likely availability of design information. Secondly, frequently re-design or re-working of drawings. Thirdly, not solving root causes of design management problems and lastly, the inadequate definition of client's brief before starting the design. The true cost of quality neglect or quality non-conformance in projects is, therefore, the total cost of meeting the client's requirements (Rounce, 1998).

In order to manage quality (and other three parameters) successfully, Public Works Department of Local Authorities (**LAs/LADPWs**) in South Africa must be characterised by effectiveness of organisational communication and decision making. Through appropriate communication, there are likely to be minimal delays in addressing, presenting and resolving problems in the **LAs** and this is likely to strengthen the ability to manage their projects.

As part of a major project, this paper report on two studies, which critically focuses on the need for municipal authorities capacity to manage PPPs projects, by looking at the implementation of **Total Quality Management (TQM)** and **Conflict Management within** Western Cape Local Authorities-Public Works Departments.

The paper reports on:

Total Quality Management

The LAs perceptions about TQM principles, commitment to implementing the philosophy, and beliefs about its effect relative to more "traditional" management philosophies; the LADPW' perceptions about obstacle(s) to successful TQM implementation in their organisations; the measures that LADPW can use to determine the success of TQM efforts; the factors that effect process quality; and finally it advances recommendations and conclusions based on the findings of the research.

Conflict Management

The LADPW's understanding of the information necessary to diagnose conflict; the LADPW's understanding on the principles of establishing claimed preference of conflict management styles; the LADPW's perceptions about intergroup and intragroup conflicts; and the approach in diagnosing conflict.

THE SURVEYS

TQM Study

The Western Cape Province consists of 20 local authorities. Ten of which were selected by systematic sampling survey as a research **sample**. A total of 31 questionnaires were distributed which represented 3 questionnaires to each of the 10 local authorities including an extra one for Cape Town Metropolitan Provincial Administration. The bias was accorded to Cape Town Metropolitan Provincial Administration due to its enormous responsibility and the fact that Cape Town Metropolitan Provincial Administration handles more infrastructure projects compared to the other local authorities.

Survey Response

As indicated in Table 1, a response rate of approximately 80 % from all the sampled LADPWs in the Western Cape was attained. Also the response rate of 32 % from the questionnaires sent was achieved.

The respondents gave various reasons as to why they did not fill in the questionnaires: ***some cited lack of interest; some claimed not to have received the questionnaire; some reported to be too busy and therefore would not spare time to fill in the questionnaire.***

Table 1 Response

Total actual sample (number)	10 LADPWs
Total questionnaire sent (number)	31
Total response of questionnaire (number)	10
Total response from LADPWs (number)	8
Percentage of response rate of questionnaires	32 %
Percentage of response from LADPWs	80 %

Familiarity With TQM Principles: The majority of respondents reported to be generally unfamiliar with TQM principles. They believed that their colleagues, their superiors, and their subordinates to be equally unfamiliar, with TQM principles.

Adoption Versus Implementation of TQM: The respondents clearly acknowledged that TQM had not been formally adopted as a quality improvement strategy.

Value Added by TQM Implementation to Current Management Practice: A majority of the respondents reported that implementing TQM principles could add value to the current management practice. They also reported that their peers are as enthusiastic as their senior management about TQM, thus suggesting existence of a broad awareness of the surveyed subject matter.

Customer Service Focus: Majority of the respondents reported that their departments had not formally identified their customers applicable under TQM principles.

The Respondents Perception on How to Implement TQM: The respondents indicated that the LAs need a comprehensive and formal TQM implementation program. In order to execute the program, respondents also indicated the need for a comprehensive TQM training for all management and non-management personnel.

Barriers to TQM Implementation: There is a clear indication of a lack of implementation of TQM in LAs.

Measuring of TQM Success: In the absence of the respondents' suggestions as to how LAs could measure TQM success, it was necessary for this study, to point out a few measures germane to LADPWs. In a similar study done in the USA's Department of Transportation (DOT) by McCambridge, *et al.* (1998), the following were found. Firstly, the use of customer surveys and focus groups (external and internal customers). Secondly, the establishing performance measures (e.g., pavement condition reports, bridge reports, design cost/total cost ratios), and thirdly formal team effectiveness reviews. LADPWs in South Africa could equally apply these measures.

According to McCambridge, *et al.* (1998) other relevant measures for TQM success, which could be applicable to LADPWs in South Africa, are:

- Change in number of and response time to customer complaints
- Reduction in number and size of tort claims
- Number of processes re-evaluated and process improvement results (e.g., shorter cycle time, cost savings, waste reduction, re-work improvements, product quality improvements and reduced change order)
- Reduced equipment down time
- Improved employee morale, productivity, satisfaction, turnover, and absenteeism.

Marketing Practices as Related to TQM Principles: Very few respondents pointed out the examples of LADPWs' efforts to enhance their image and how successful/unsuccessful they have been. Examples could have included: preparation of budgets and conducting of public meetings; subdividing the LADPWs into smaller task sections aimed at servicing specific client, such as education-schools, health-hospitals etc.; and writing and delivering national and international papers for conferences or journals.

Testing the Hypothesis: The research results strongly suggest that there has been a lack of knowledge on TQM implementation in LADPWs in the Western Cape Province. And there are strong indications to suggest that this has led to poor quality of work.

The hypothesis is therefore true that: **Within the local authorities departments of public works there is a lack of understanding of Total Quality Management. This has led to poor quality of work.**

Risk Management Study

The study was carried out based on developments in conflict management – theory and practice (Rahim 1992; Robbins 1978; Vlatas 1991; Davis and Scott 1969; Tjosvold 1989; Brown 1993; Singh and Vlatas 1991; Rwelamila 1989; Chester *et al.* 1978). The method of collecting data from the participants was divided into three categories which are the mailed questionnaire, telephonic and personal interviews, and it was assumed that this size will be sufficient to be representative of the survey. The sample size was structured as shown in Table 2.

Table 2 The sample size structure

	Project Manager Public Facilities	Project Manager Housing	Building Inspector
Mailed questionnaire	20	20	20
Telephonic interviews	6	6	6
Personal interviews	6	6	6

Survey Response

Supervisor Conflict : A substantial majority of the respondents reported that they prefer to use a problem-solving style when they interact with the supervisors. This also demonstrated that there is commitment within the LAs to give cohesion and good orientation, which will help the LAs to uplift the organisational effectiveness that will maximise resources and output.

Co-worker Conflict*:* The LAs promote problem solving, which advocates a direct confrontation with the problem. This management style therefore bridges the gap caused by the communication breakdowns that could cause delays in addressing the fundamental problems within the organisation. Compromise was chosen as the next best management conflict style, hence an indication that there is a willingness within the organisation to meet the problem at the middle ground by bargaining and searching for solutions.

Subordinate Conflict*:* The majority of supervisors in the LAs value problem-solving management style. This management style suggests giving an organisation a foresight, complacency and group effectiveness.

Intragroup Conflict Frequency*:* The major sources of conflict in projects environments' results, tend to follow the same trend for all the sources of conflict, that is, the respondents reported that these conflict sources seldom occurs in the intragroups of the LAs.

Intragroup Conflict Intensity: The results showed that there are significant differences between the respondents' views of sources of conflict and how the latter will impact on the LAs. All the conflict sources revealed that a greater percentage of the results indicate a slight impact. The results strongly suggest that, even if these conflict sources are there, they have little or no impact on the running of the projects in the LAs.

Supervisor Conflict: The results demonstrated that a substantial majority of the respondents prefer to use a problem-solving style when they interact with the supervisors. This also demonstrate that there is commitment within the LAs to give cohesion and good orientation which will help them to uplift the organisational effectiveness that will maximise resources and output.

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Intragroup Conflict Intensity: The results showed that there are significant differences between the respondents' views of sources of conflict and how the latter will impact on the LAs.

Intergroup Conflict Intensity*:* Results suggested that, between the departments of the local authorities, there were no observations and reports that might help the organisation to use correct procedures of conflict diagnosis in times of need.

Testing of the Hypothesis: Based on the findings from the intragroup and intergroup conflict section, it was established that both frequency and intensity of the major sources of conflicts are low. This suggests that the LAs fall within the zone of complacency in the conflict balance. The zone of complacency means that there is low level of conflict, no stimulation, little cohesion, and no feedback and goal orientation and as a result, there is a dominant destructive environment.

Therefore, this research demonstrated results that positively suggest that, indeed, the LAs are suffering from low levels of organisational conflict, which have led to poor organisational effectiveness.

CONCLUSIONS AND RECOMMENDATIONS

From the two research studies reported above, it is clear that the key PPP challenge facing South African Local Authorities is to improve their understanding of 'value for money' in their choices of infrastructure and project delivery options. If these local governments are to provide essential urban services in a way that spreads the benefits of development to all citizens, Local Authorities professionals must begin to experiment with the innovative project delivery systems that have been developed and used successfully elsewhere. This means that all forms of municipal service partnerships must be used, where appropriate, with the primary criterion for selection being the practical benefits for average citizens. Local Authorities will not be able to experiment with the innovative project delivery systems unless their professionals have sufficient capacity to embrace 'better practices' in project delivery systems. The following conclusions and recommendations are advanced on the basis of creating efficient and effective municipal service partnerships (MSPs)

Conclusions

Based on the research findings, the following conclusions may be drawn:

- There is a total lack of TQM understanding within the LADPWs, which is partly the cause of poor quality of products and services that they render to their clients.
- TQM had not been formally adopted as a quality improvement strategy. The LADPWs showed no commitment to implement TQM principles in their operations.
- LADPWs perceive the need to implement TQM as a means of improving quality of their products and services to their clients.
- Contrary to the findings of similar studies elsewhere, USA in particular, the "resistance to change" forms one of the potential barriers to TQM implementation.
- Few respondents pointed out the examples of LADPWs' efforts to enhance their image and how successful/unsuccessful they have been.

- LAs prefer the problem-solving conflict management style.
- There are low levels of frequency and intensity in the intragroup and intergroup conflicts within and among LAs.
- As a result of the withdrawal style, differences are suppressed, communications between parties in the LA are reduced and parties seem to avoid potentially controversial interactions.
- Generally, LAs have no mental stimulation and yield destruction when sources of conflict are evaluated. Since the stimulation level is low there is no goal orientation, no feed back and cohesion among the members of the departments.

Recommendations

The above two research project results regarding TQM and conflict management , strongly suggest that South African municipal authorities are facing a significant lack of management capacity in PPP delivery systems. There are strong indications to suggest that inefficiencies seem to characterise the majority of LAs -- hence the lack of capacity in best use of scarce resources (the foremost resource being human resources).

The Municipal Infrastructure Investment Unit (MIIU) was set up to empower both municipal personnel and the private sector to become more competent and confident in handling this new business – PPP delivery systems.

The following recommendations will help the MIIU to improve LAs capacity in handling PPP based delivery systems:

- There is a need for an intensive skills audit of all LAs, in order to establish current skill levels and identify skills gap which need to be filled in order to deal with the requirements of managing PPP based delivery systems.
- In order to place service delivery through PPPs on a commercial footing, considerable investment must be made in human resources – developing skills, introducing new management systems and incentives, changing the culture of LAs organisation and creating a sense of purpose and responsibility.
- The MIIU should consider to subcontract some resources perhaps to emerging entrepreneurs in the community in which

services are rendered. Such arrangements can be mandated in contracts if a LA regard this as a priority.

- Capital finance is an important ingredient in facilitating PPP based delivery systems. MIIU should initiate measures to make sure that there are appropriate approaches in raising capital – raising capital can only be done against realistic projections of investment needs and expected income.

- MIIU need to provide a sound funding system, which should create an environment where banks will be brought into the process early on and their concerns addressed. They may well be able to propose innovative funding arrangements.

- To be effective, a service provider in a PPP based delivery system must understand the market in which it operates. The MIIU should initiate best practices within LAs whereby a commercial approach framework characterises PPP based delivery system practices – this will create a culture of understanding customer needs, managing relationships and getting the pricing and the infrastructure product right.

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Changing of Building Construction System and Propagation Process of Construction

Management System in Japan

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ABSTRACT

There are three main characteristics in the building construction system of Japan. The first is the existence of the continuing long-term relationship between the general contractor and the subcontractors. The second is even if the scopes of responsibility and authority are not clear among the stakeholders who may be the client□the designer□the general contractor and the sub-contractor, the relationship and mutual trust of the stakeholders are strong. The third is, at present, the project procurement system is basically limited to a traditional way, either "design-bid-build" or "design-build". The separate contract system and the construction management system (hereafter referred to as CM) are still rarely used.

However, for the changing and internationalizing of construction environment, the diversification of client's demands, the shrink of Japan's economy, and the increasing of sub-contractor's capability, the three characteristics mentioned above are changing gradually from now on. Generally, the expectation for CM is high. In particular, many projects in the private sector where CM being put into practice, are reported to be the instances of new procurement system.

In this paper, we would like to discuss the way CM is being introduced into the building construction system of Japan, CM's current state, and the problems that exist.

HISTORY OF THE INTRODUCTION OF CM

The conditions to introduce CM into Japan greatly differ between the public and private sectors. In the public sector, there are investigations being carried out by the Ministry of Land, Infrastructure and Transport(MOLIT); however there is not any practice in any project at this stage. In the private sector, although the legal system and contract stipulation are not yet adequately prepared for CM, more and more projects are carried out by CM gradually. The outlines concerning the introduction of CM in public and private sectors are described below.

History in MOLIT

According to the recent committee report on the construction industry and the bidding system in the MOLIT, the trends concerning CM are shown in Table 1. Three key points are found from the trends. First, the construction industry can be divided into several segments, and MOLIT makes the strategy for each segment. Second, the administration of MOLIT which guided and fostered the industry in the past, is now moving more towards the view point of the procurement of buildings. Third, related to this situation, it is paying more attention moving more towards soft technology.

Table An Examination of CM in the MOLIT

1992	Report by the Central Council on Construction Industry CM was reported as an alternative bidding system, which was in fact never put into practice.
1993	US-Japan Construction Talks The US Government demanded that Japan introduce CM, and implement a project to test this introduction.
1995	General Principle of Construction Industry Policy The structure and future vision "new era of competition", as well as a fundamental policy of construction industry was shown. The prospects for the construction industry in the mid and long term up until 2010 were also presented. Within this, the setting up of systems to support provincial clients through the system such as CM was described.
1996	Strategic Program for Construction Industry Reform This is the support policy by the government. Especially, it emphasis on supporting small and middle-sized contractors which are finding themselves in today's fiercely competitive environment. However, nothing about CM was mentioned.
1999	Construction Industry Revival Program According to the General Principle of Construction Industry Policy, an important topic was focused. Emphasis was laid on the future vision of large-scale general contractors. For CM, it was said that with the intensification in competition in the construction industry, it is necessary for the general contractor to construct a management system such as CM, etc. The popularization and promotion of CM are also being encouraged in the government.
2000	Innovation Strategy for Specialist Contractor By providing a guide to a future strategy, such as management reform of the specialist contractor, which may create various construction production/ management systems such as CM.
2001	CM Research Committee Not only extracting and discussing the problems likely to occur with the introduction of CM in both the public and private sectors, but also investigating into relevant laws and ordinances which should be set up.

History in Private Sector

The trend introducing CM into the private sector is summarized in Table 2. Three key points are found from the trends shown in this table. First, 10 years have passed since CM was first actually used in a project. Second, CM was not used as a whole system of services, but partial services of consultant. Third, architects have positively started to embrace CM services.

Table 2 An Examination of CM in the Private Sector

1970's- The state of CM in the USA was catching people's attention. But the Japanese customary and contract system was unfamiliar with CM. Thus, its introduction to Japan was postponed.

1980's-The situation pointed to EC(Engineering Constructor) is mainly focused on design-build system. This was a period of development by private companies of such management systems as TQC and VE, rather than CM.

1990's-First half. Because of the bubble economy in Japan, new management systems were searched to ensure as the effective means of large-scale investment in construction. CM was one of them. Consultants also had been emerged to provide partial services of CM such as bid management, separate contract, value management. Many of them have the backgrounds concerning architects.

1993 The PM Special Research Committee was established in Architectural Institute of Japan(AIJ).

1990's-Second half. Along with the depression in the economy, transparency in the process and the cost of construction projects was demanded, and fee-business became increased. The project performed by using CM became normal.

1998 JFCC (Japan Federation of Construction Contractors) suggests that CM charge the soft services.

1998 JIA (Japan Institute of Architects) published "JIA-CM Guidelines", which was claiming that services of CM should be the extensional services of the architect.

2001 CMAJ (Construction Management Association of Japan) was established. The main purpose of its establishment was to "resolve any confusion which has occurred due to various assertions regarding CM from different organizations and companies, to innovate Japanese construction system reasonably". There are 380 members of this association in October 2001. The work standards, qualification systems and ethics codes are in the process of being set up.

THE PRESENT SITUATION ABOUT CM IN JAPAN

The research about CM was being carried out internally from the era of the Ministry of Construction, and the committee with the name of "CM Research Committee" was formally started by MOLIT in the end of 2000. The conditions for CM qualifications or the introduction of CM for the bidding of public construction projects had commenced investigation.

On the other hand, CM has been used in private projects by a number of different types. At present, whether it is used as the partial service of CM or whole service of

CM, it is being principally carried out by the organizations concerning the architect. For example, according to CM carried out in Architectural Office "I", CM is used completely separate from the design service, and is used as an independent business to co-ordinate the client, the architect, and the contractors. Also, in another Architecture Office "N", the design service and CM are often accepted at the same time. Although it is not called CM in provincial areas, the separate contract system is also being practised by many architects. As a result of separate contract system without general rules and standards, some claims and unreliability have drawn on CM services.

Gradually, many large-scale general contractors are also beginning to establish CM departments, or CM groups within their companies, and are carrying out full CM services mainly for the construction projects of foreigners' investment. However, CM has not been tried in actual projects which the client belongs to affiliated company, and the rich CM experience obtained from overseas projects is not being utilized. The general contractor is also now in conflict as to choose whether the profit of single responsibility of lump-sum contract like before or the fee of CM. It may be in the process for them to search the strategies from now on. However, if public clients chose to whole-heartedly introduce CM, the organization of the general contractor should become very unclear and flexible immediately.

The firms specialize in CM services are also appearing. Firm "B" has been very successful in providing CM services for over 10 years, but recently, the demand for CM has rapidly begun to increase. Also, Firm "A" is mainly providing services of market survey, architectural planning, bidding document, and design review(DR, VE/ VM) at the design stage. After sufficiently listening to the client's doubts and worries, and providing a flexible and manoeuvrable resolution, they gain the appreciation of clients. This service is similar to a counsellor's activities. Especially, the clients of large-scale companies which belong to the electrical and railroad industries have also been seen recently beginning to research into CM.

CONSTRUCTION ORGANIZATION UNDER CM

Basically, CM may increase the benefits such as the clear specification of cost and reduction of schedule by separating the bids of subcontracting. So what the construction organization (definitions as follows) will be in the current situation of Japan when the project uses CM will need to be discussed. Here, the projects used single responsibility of lump-sum contract and CM were investigated to realize the current situation, and to clarify the construction organization which these two procurement systems are used.

Outline of Investigation

The outline of the investigation is as follow:

- Entity: 5 general contracting companies, 5 CM firms (with each company providing 3 actual project examples)
- Method: Questionnaire
- Content: Project summary, contracts related to the project, allocated responsibility for the work, the reasons for this allocation, and the allocation process
- Term: July- September 2000
- Number of responses: 14 responses from general contractors, and 10 responses from CM firms are received as valid samples

Problems in Construction Organization

The problem of construction organization means to combine a number of resources for multipurpose under a set of constraint conditions as the building can be constructed. Multipurpose means in terms of schedule, cost, quality, and safety, etc, and a number of resources means in terms of labor, materials, machine/equipment, etc. The basic problems in construction organization can be divided into the following:

#1 Selection of the subcontractor with whom to issue the bid

This problem is to decide the best bidder of subcontractor by multipurposely evaluating various decision factors such as cost, long-term business relationship, and the ease of management, etc. These qualitative factors are the large implications to the problem.

#2 Selection of subcontractor for each trade

This problem is to select a subcontractor for each trade, and also evaluate many different factors as shown in #1 under all the constraint conditions in a project.

In selecting a subcontractor with whom the general contractor issue the bid for each trade, the problems of construction organization can be described as an construction organization matrix. This matrix is shown in Figure 1. The horizontal axis is the type of trade, and the vertical axis is the type of job.

If we simplify construction organization, each cell of this matrix can be regarded as the subcontractor to issue the bid. In Figure 1, same colored areas of the matrix means the selection of the same subcontractor. When all the cells are allocated into one or more of these subcontractors, the execution of the project becomes possible.

In order to present the problem of construction organization, the appropriate horizontal and vertical axes were examined and shown in the figure due to the results of this research. Then the definitions are described as below. The example was shown in Figure 2 concerning the construction organization of building structure. The "-" in the figure means that there is no job relevant for that cell.

■Vertical axis(job)

1. temporary works/equipments(t-equipment)□

2. labour□

3. materials□

4. additional materials(add-materials)□

5. shop drawings□

6. schedule control(s-control)□

7. quality control(q-control).

■Horizontal axis(trade)

1. earth work(e-work)□

2. steeplejack- scaffolding□

3. steeplejack- erection of steel frame(erection)□

4. concrete laying work(concrete)□

5. formwork□

6. reinforcing,

7. steel work.

	trade 1	trade 2	trade 3	trade 4
job 1				
job 2				
job 3				
job 4				
job 5				

Figure 1 Construction Organization Matrix

	e-work	Steeplejack		concrete	form work	reinforcing	steel work
		Scaffol ding	erection				
t-equpments							
Labour							
Materials			—				
Add-materials							
Shop drawings			—	—			
s-control			—				
q-control							

Figure 2 Matrix of the Construction Organization in Structure Works

	e-work	steeplejack		concrete	formwork	reinforcing	steel work
		scaffolding	erection				
t-equipments							
Labour	a	b	b	b	c	d	e
Materials	a		—		c		e
Add-materials	a				c		e
Shop drawings			—	—		d	e
s-control	a	b	—		c	d	e
q-control	a	b	b		c	d	e

Figure 3 Construction organization matrix in project "B" by general contractor "A"

The Situation of Construction Organization

(1) Construction organization by the general contractor

14 projects can be divided in detail: there are 10 projects issued to the construction as one package to the general contractor, only one project was issued equipment work as a separate package, and 3 projects were issued the design-build to the general contractor.

An example of construction organization by the general contractor is shown in Figure 3. Cells with the same alphabet letter indicate that the work was issued to the same sub-contractor, and an empty cell means that the work was done by the general contractor himself.

As shown in Figure 3, sub-contractor "b" acquired the 3 trades of steeplejack-temporary scaffolding□steeplejack- erection of steel frame□and concrete. Also, it would usually be the case that sub-contractor "b" would also have concrete laying work. But in this project, sub-contractors were selected by bids between 3 cooperative companies. Sub-contractor "e" is issued almost all works concerning the erection of steel frame. Even if the works of other sub-contractors were examined, many of these works are in the areas other than labour. These types of work allocation for the construction organization are no longer unique, but becoming common in the construction projects now.

The main factors concerning the decision of construction organization extracted from the projects were noted as below.

- Increasing the number of work cells as many as possible to a single subcontractor in order to reduce costs.

- Selecting a system which would generally shorten the schedule.

- Contracting with subcontractors in form of JV to shorten schedule due to the amount of work is large.

- Reducing the number of subcontractors and selecting ones who can manage all works totally.

- Selecting the subcontractors who can handle quality management independently.

- In the case of an RC high-rise building, placing importance on ensuring quality.

- The demands of the client and architect.

(2) Construction organization by CM Firms

In the 10 investigation projects, 4 projects relied on the general contractor for construction as one package (2 of these projects were using the "cost-on" for equipment work), 3 projects separated equipment work from construction package, but the construction of architectural work as one package relied on the general contractor. And 1 project relied on the general contractor by using design-build, the bid packages for the rest of 2 projects are different from the others.

Generally, the popular way is that the construction concerning architectural work as one package relied on the general contractor, and only the jobs such as management quality are issued to CM firms.

The example shown in Figure 4 is the construction organization of project "D" implemented by a CM firm "C".

	e-work	steeplejack		concrete	form work	reinfo rcing	steel work
		scaffold ing	erection				
t-equipme nts	a	a	a	a	A	a	a
Labour	a	a	a	a	a	a	a
Material s	a	a	—	a	a	a	a
Add-materials	a	a	a	a	a	a	a
Shop drawings	a	a	—	—	a	a	a
s-control	a	a	—	a	a	a	a
q-control	a	a	a	a	a	a	a

Figure 4 The Construction Organization Matrix in Project "D" by Firm "C"

As shown in Figure 4, all the trades and jobs are issued to the trader "a". The contractor of this trader "a" is not a subcontractor, but the general contractor. The general contractor organized all the trades and jobs for construction by himself. This means that the general contractor is basically organizing the whole project by himself. It is similar to project "D". It could be found in the most projects of CM firms that the construction organization is essentially carried out by the general contractor, when all projects of CM firms were examined.

The main factors concerning the decision of construction organization extracted from the 10 investigation projects were noted as below.

- Placing importance on ensuring quality in equipment work by using the "cost-on" (CM Firm J).
- How to successfully keep the balance of reasonable construction cost and quality assurance(CM Firm E).
- How to extract management capability of the general contractor out (CM Firm E).
- How to utilize as much as possible the technological and management techniques possessed by Japanese general contractors(CM Firm E).

- How do utilize a general contractor with a high capacity of schedule management, coordination, and safety management, etc (CM Firm J).

- The majors of project are followed to the client's decision, but it is best to utilize the general contractor as much as possible, because the general contractor has very high capacity about construction/procurement management in construction site(CM Firm L).

- Even if the project is issued by the separate contract system, it is better to collect the related jobs in one package as much as possible(CM Firm L).

Summary of Results

The results extracted from the investigation were surmised as follows:

- The construction organization of CM relied on the existing general contractors and their construction organization, and the characteristics of CM are not being used to the extent they could be.

- One of the reasons for the above-mentioned is that the relationship of risk allocation cannot be clearly defined at present.

- There are various types of construction organization being carried out by general contractor under the single responsibility of lump-sum contract. It is obvious that the area of trade and job able to be done by one subcontractor is expanding. And it is urgent to have a new system to construct a reasonable construction organization.

- It is necessary to closely readjust the function of CM in a CM system, the function of GC in a GC system, and CM's organization/GC's function in a CM system when GC is jointing in.

CONCLUSIONS

At present, the main functions of CM extracted from the investigation include how to make the biding process smoothly and how to coordinate successful bidders effectively, in order to intensify the competition of biding, and to reduce construction cost as much as possible. That means the major work of CM is "Bid Management". Certainly, it is a very important work of CM and never change. But in Japan, the basic work of CM is to deal with the clients' needs, which seems to be the key to success. It is important to draw out those needs and desires from the client smoothly. In other words, it is now demanded that companies also function as a form of counsellor.

The three technical problems for CM are summarised as follows:

1. It is required to implement the works such as value engineering, constructability, and buildability which are concerning production design in the design phase.

2. Also, as experienced by Architectural Office I, a certain level of knowledge to understand the content of certain trade and work is necessary to carry out bid management when the project uses the separate contract system. CM is required to have the capability to effectively implement the works such as temporary work, procurement plans, information for lead-time, and schedule management which are relied on contractors in the past.

3. Essentially, the design of a project organization in a CM system is a combination for the basic services of CM. But compared with the single responsibility of lump-sum contract used as usual, CM provides a more beneficial design for each project. It is one way that implements CM as American style, but taking Japan's particular characteristics and attempting to put them into CM is another way.

In addition to this, there are many problems to be addressed such as quality assurance in CM, and completion guarantee with the separate contract. But the important thing is that CM is implementing, even if it be only the partial services of CM. It can be ascertained that a new style of CM much more suited to Japan would be emerged gradually.

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Mapping of Knowledge Brokers: The case of Danish Building

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ABSTRACT

This paper reports the empirical mapping of knowledge brokers in the Danish business system of building construction – i.e. institutions such as universities, national research centres, professional organisations, standards organisations, trade organisations etc. – and a preliminary analysis of their role in building innovation. An underlying premise of the paper is that knowledge brokers are producing and/or disseminating knowledge, which is crucial for successful innovation in a complex systems industry such as building construction. The mapping of knowledge brokers was undertaken through three steps: (1) interviewing key decision makers to establish an overview of organisations/institutions, (2) undertaking a comprehensive survey aimed at identifying and characterising all relevant knowledge brokering organisations in the Danish context, and (3) examination of 200 knowledge brokers' web-sites. In total approximately 300 knowledge brokering organisations were identified. On this basis, we arrive at a typology of brokers with different characteristics and roles in the business system. The research reported in the paper is part of work undertaken by Danish researchers in the context of the CIB TG47 task group: "Innovation Brokerage in Construction".

INTRODUCTION

The research, reported in this paper, is the first step in a detailed investigation of the role of knowledge brokers in construction innovation processes. The purpose of the paper is to map the knowledge brokers which are active in the Danish building sector and provide a typology of the different types of brokers. The research reported in the paper is part of work undertaken by Danish researchers in the context of the CIB TG47 task group: “Innovation Brokerage in Construction”.

Knowledge brokers facilitate knowledge flows and learning processes in the building business system in general and in innovation specifically. As intermediaries, knowledge brokers translate advanced research into information that is useful for construction firms. Furthermore, brokers may secure feedback, which helps formulate relevant research questions, based on the needs of firms.

Studying knowledge brokers is important for many reasons. The Danish building sector – as is the case in many other countries – is characterised by a large number of small and medium-sized firms with only limited resources for knowledge production and accumulation of their own. The knowledge brokers form one of the main elements of the R&D and innovation system, but their role is surprisingly unexplored.

When referring to construction as a “Complex Product Systems” industry (see Hobday 1998 and Winch 1998) Winch argues (Winch 2000) that innovation in construction is rarely a single firm effort. Rather, construction innovation relies on knowledge inputs from many different sources and is negotiated between large numbers of stakeholders in inter-organisational project coalitions. Knowledge brokers (or innovation brokers, which is a narrower term used by Winch) often facilitate these knowledge flows and negotiation processes.

Earlier studies of imperfections in Danish public innovation programmes conclude that knowledge brokers are generally insufficiently activated in these programmes (Bang *et al* 2001). For example, there is generally a low awareness of the potential effect of engaging knowledge institutions more directly as change agents in innovation processes. Also R&D institutions should be more consistently employed in evaluating the outcomes of public programmes. Furthermore, education and training institutions need to participate – to a greater extent than is usually the case – in processes concerned with implementation of new technology in construction.

Figure 1 provides a simplified illustration of how the basic structure of the Danish R&D system is traditionally perceived. The illustration reflects a strong reliance on a diffusion strategy. In this (linear) model each level of the system produces outputs that are transferred to the next level as inputs. Thus, outputs from basic research are inputs to applied research etc. – through to various stages of development and commercialisation. In that way knowledge is undergoing a process of refinement and adaptation from universal theories and principles to specific applications in practice. Knowledge brokers may act as intermediaries in this process of diffusion and dissemination.

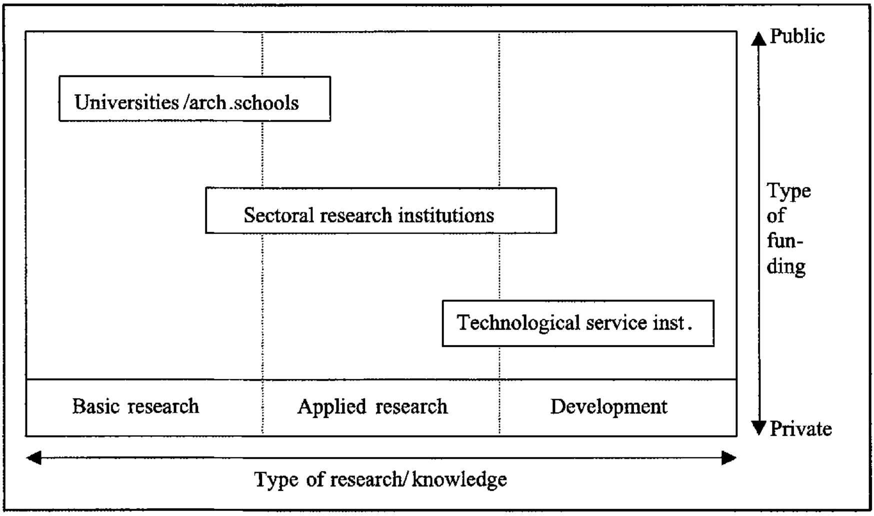

Figure 1: The basic structure of the Danish research and development system

The model has often been criticised (e.g. Steinmueller 1994), but is nevertheless – at least implicitly – an underlying premise for many government interventions and public R&D and innovation policies. We will not here comment further on the shortcomings of the linear model, but use the model as a starting point for our analysis of the role of knowledge brokers in the Danish building sector. From this perspective, the purpose of the paper is to put forward a more differentiated and empirically substantiated understanding of the composition and the knowledge flows of the Danish building R&D system.

METHODOLOGY FOR DATA COLLECTION

The data presented in this paper comes from two studies initiated by the Danish Ministry of Housing and Urban Affairs. In the first study, data was collected as part of the work of a governmental task force concerned with knowledge dissemination in the Danish building sector in 1998 (Bang 1999). As part of the activities of the task force it was attempted to map the knowledge brokers in the Danish building sector, and ask each of them a few fundamental questions regarding their activities:

1. Contact person, name of knowledge broker, address, home page
2. Other knowledge brokers that should be added to the list for completeness
3. Important targets for communication and dissemination of knowledge

4. Coverage with respect to different kinds of firms and organisations
5. Main areas of knowledge that the knowledge broker is focused on
6. How the knowledge is communicated/organised with respect to search structures
7. Which media are used in the communication and dissemination of knowledge.

The data collection took place through an iterative process, which was initiated by a brainstorming among the members of the task force aimed at identifying the main knowledge brokers in the Danish building sector. It was decided not to include private firms and trade magazines etc. in the mapping process. The questionnaire was then mailed to the organisations and their answers to question no. 2 were used for mailing another round of questionnaires etc. Three rounds of questionnaires were mailed to a total of almost 300 organisations. Approximately 150 replies were received.

The second study – which was carried out in 2001, was based on an examination of the web-sites of approximately 200 of the above mentioned knowledge brokering organisations, yet, including private firms. The purpose of this study was to identify their dissemination strategies, which segments of the building sector they target, and which types of communication (channels) they use.

A TYPOLOGY OF KNOWLEDGE BROKERS

In this section we summarise the results of the survey described in the previous section. The organisations identified are divided into twelve groups of different knowledge brokers ranging from universities and other educational institutions over professional organisations to certification and control schemes. The twelve groups are listed in appendix A with examples of activities and actors. Here follows a brief introduction to organisations and institutions in each group including their basic characteristics with regard to, for example, objectives, co-operative relationships and dissemination strategies.

Education, training, courses

This category encompasses institutions such as universities and other kinds of higher education, technical colleges for training of trades people and organisations offering shorter courses to semiskilled and unskilled workers. Interestingly, although most institutions are under the auspices of the Ministry of Education, architectural schools are under the Ministry of Culture and the organisations offering shorter courses and vocational training are under the Ministry of Labour.

Conceptually, we may differentiate between knowledge dissemination to students and to firms – i.e. focus on individual learning vs. focus on direct interaction with firms. It should be observed that universities are concerned with research and teaching – other institutions are engaged in teaching without research. Dissemination via teaching is most important for the institutions under this category. For technical areas dissemination also takes place through consulting and advice, and for architecture also through exhibitions etc. Publication is through reports, academic articles and in trade magazines.

With regards to knowledge search as part of education, the focus is especially upon sources regarding legislation and regulation, manufacturers' catalogues, sectoral research institutes and dedicated knowledge centres. Knowledge search frequently includes use of electronic facilities such as Internet, CD-ROM, databases etc. Judging from the examined web-sites, dissemination strategies concerning the building sector are rarely specified.

Sectoral research institutes, government laboratories

This category includes institutes concerned with building generally (Ministry of Housing and Urban Affairs), surveying and cadastre (Ministry of the Environment), Energy (Ministry of Energy and Urban Affairs) and several others. Most institutes are associated with a ministry (government department) from where a sizeable proportion of funding is provided. A few institutes are formally independent from government departments.

Most of the institutes primarily target public authorities and public clients in addition to consultants and trade and professional organisations. Communication with target groups is primarily through publications, and Internet home pages. Some institutes (typically the independent ones) engage in provision of courses and in consulting. The government laboratory concerned with energy is especially noteworthy in targeting directly the Danish households as part of its efforts to reduce energy consumption.

Approved technological institutes etc.

This category is made up of institutes, which are approved by the Agency for Trade and Industry (Ministry of Business) and receive a limited public funding (approximately 15 percent of the total turnover). The rationale is for the technological institutes to uphold a level of technical competence from which any business firm may procure when necessary. There are approved technological institutes in areas such as building technology, fire, materials testing, hydraulics and standardisation.

The technological institutes target especially consultants and various kinds of contractors in addition to building owners and clients. They mainly engage in consulting and advice (on a fee basis), yet, also activities such as courses and publications are important.

Dedicated knowledge centres

In the mapping process two different groups of dedicated knowledge centres emerged. One group of centres is mainly publicly financed and each centre is dealing with a specific area such as architecture, ecology, standardisation of drawings and specifications etc. A wide range of dissemination strategies are used (e.g. exhibitions, reports, networking, websites, workshops etc.). Standardisation of drawings and specifications takes place on a voluntary basis through membership of BPS. Another organisation (BYG-ERFA) is involved in analysing experience-based problems and specifying solutions to avoiding and rectifying them. For each problem identified, BYG-ERFA draws on the experience of a selected team of experts from universities, sectoral research, approved technological service institutes etc. The resulting guidelines are issued as fact sheets, which bear obligation for construction firms with respect to quality assurance.

The other group of dedicated knowledge centres is primarily privately financed and centres are typically formed around certain materials. There are centres within areas such as masonry and brickwork, wood and timber, roofing, flooring, cement and concrete. Producers of the relevant building materials often sponsor them. The activities of the centres are typically focused on consultants and on various kinds of contractors (often specialist or trade contractors). Other kinds of firms and authorities and the educational system are also mentioned with regards to dissemination. Typically, the centres are involved in publication of written guidelines specifying how to use the relevant materials correctly. Some centres also engage in courses and teaching, in consulting and advice and in news services. A few centres are engaged in quality control schemes etc.

Trade and professional organisations

As observed for educational institutions there is an important divide between activities aimed at individuals and firms. Some organisations represent employees and other employers. Especially noteworthy for employees are professional organisations for architects and engineers and unions for skilled and semiskilled workers (carpentry, masonry, concrete etc.). For employers, architectural and engineering consultants are noteworthy, as are general contractors and trade and specialist contractors. Furthermore, there are a number of supplier organisations (merchants, building materials, mechanical and electrical components, plastics etc.).

The various organisations communicate with their members through a broad range of activities. The employee organisations mainly communicate through courses, publications and news services. Communication with skilled and semi-skilled workers is facilitated by an extensive distributed network of union representatives. The employer organisations are typically engaged in communication of issues regarding new legislation, rules and regulations. They rely more on consulting and advice than the employee organisations – regarding procurement, technical issues and new products and materials.

Libraries/databases

There are two main libraries within building – with reference to specific major educational institutions within architecture and engineering. The Danish National Centre for Building Documentation is associated with the School of Architecture at the Royal Danish Academy of Fine Arts. The Technical Knowledge Centre and Library is associated with the Technical University of Denmark. Furthermore, there are a number of other libraries associated with, for instance, the Danish Building Research Institute and the Horsens and Copenhagen Polytechnics. These libraries cooperate with the main ones with regards to databases etc.

BODIL is the main Nordic database for building and civil engineering publications (approx. 25,000 abstracts) whereas ICONDA is an international database for construction. Furthermore the main libraries have their own databases for scientific publications from the relevant educational institutions, e.g. ARTUR, VIGGO, KARL, ALIS and DADS. Moreover, there is a general database covering all Danish research publications (DANDOK). Especially researchers and students make use of the libraries and databases. Very often, the libraries undertake searches in the databases on behalf of researchers, students and firms.

Public authorities etc.

Traditionally the Ministry of Building and Urban Affairs has been central in administering legislation and regulation in building – and in supporting R&D activities in building by way of demonstration projects. In recent years the Agency for Trade and Industry (Ministry of Business) has increasingly involved itself in development programmes aimed at promoting innovation in the building sector.

The Ministry for Environment and Energy contains two agencies, which are dealing with specific knowledge concerning buildings and construction. The Danish Environmental Protection Agency has for a number of years initiated and financed projects on cleaner technology, and the Energy Agency is responsible for energy savings in buildings.

Various other kinds of public authorities are engaged in administering legislation and regulations, e.g. issues of safety regarding, for instance, electrical installations. Danish municipalities and counties are also engaged in administering legislation and regulations through local planning etc.

Client organisations etc.

A number of client organisations are especially notable because they are publicly funded and thus statutorily obliged to engage in experiential knowledge accumulation and dissemination as part of their activities. Especially non-profit housing associations, the building agencies of state departments and ministries and the urban renewal companies have special obligations in that regard (most notably the ministries of Housing and Urban Affairs, Education and Defence have sizeable building operations). An important part of their dissemination is by being "demanding" buyers in direct interaction with consultants and contractors. Private clients generally have less explicitly stated aims with regards to knowledge dissemination.

There are a number of organisations for both tenants and for building owners and landlords (many tenants are individuals – whereas most owners and landlords are firms or organisations). Many of the organisations communicate to their members and others via courses, news services and publications.

Standardisation, certification and control etc.

Certification and control schemes concern a wide range of materials and components (and procedures) – such as mortar, concrete, tiles, windows, timber and trusses. Independent parties are concerned with subjecting production and products to quality control according to standards and norms. The dissemination of knowledge is twofold – to producers of the relevant materials and components and to potential users in terms of consultants, contractors and clients. In addition to control activities at producers' facilities, the schemes often involve communication via courses, news services, consulting/advice and publications. Approved technological service institutes administer many of the schemes.

Certification and control schemes should be seen in conjunction with activities concerning standardisation and norms (e.g. *Dansk Standard,* which is an approved technological service institute).

Private companies

The private firms in building construction also serve as knowledge brokers. The survey shows that architects and engineering firms are important suppliers of knowledge for other firms in the sector. Especially consulting engineers often function as key points of communication with regards to knowledge flows in construction project organisations and throughout the entire construction process. Furthermore, manufacturers and wholesalers of materials and components recommend specific technical solutions and in some cases provide software for economical and technical calculation.

It is notable that the building merchants potentially have a particularly broad-based contact to contractors (and to manufacturers) – since especially trade contractors are in contact with merchant firms whenever building materials and components are purchased.

Public development programmes

The Danish Ministry of Housing and Urban Affairs is actively promoting technological change by setting up R&D programmes targeting specific areas of the built environment. Current examples of major development programmes are Project House, Process and Product Development in Building and Project New Partnerships (for a more detailed analysis, see Bang et al 2001).

Traditionally, various types of firms in the building sector carry out these programmes in temporary project organisations. Demonstration projects are used as the main implementation strategy – including reports, workshops and networking activities as knowledge dissemination instruments. The demonstration project strategy has often been criticised for ambiguous results, poor dissemination and, generally, a low impact with regards to changing traditional building practice. Generally, there is a lack of awareness of the potential effect of involving other knowledge brokers and educational institutions more directly as change agents in R&D programmes.

General knowledge dissemination

There is a broad range of organisations and networks involved in general knowledge dissemination. A prominent example is the Building Information Centre, which is a one-stop distributor of publications for firms in the building sector – in addition to information distribution via courses, conferences, exhibitions, home pages, news services etc. Each year the Building Information Centre is in contact with 25,000 individuals in the building sector. For co-ordination of research and development activities, 23 of the main institutions (most of which are publicly funded, to some extent) have formed a network (*SOFUS-Byg*), which functions primarily as a forum for information exchange and discussion.

A number of the trade organisations and the materials information centres have established boards of appeal – with respect to especially the services of specialist and trade contractors. Hence, these boards function as a kind of guarantee schemes for customers/clients and at the same time provides knowledge for the organisation of where updating of knowledge is necessary to avoid the defects that are frequently experienced. A more general public initiative is the operation of building defect funds – one for new building and one for building refurbishment. The funds are insurance schemes, in the sense that for all publicly funded building projects a percentage of the total cost is paid into the fund and after one and five years upon completion, the buildings are inspected for defects. If the firms involved cannot be made responsible or do no longer exist, the fund pays for rectifying the defects. Each fund publishes the results of its inspections and attempts to highlight the most critical problem areas.

There is a large number of local chambers of commerce spread over Denmark – which have the potential to communicate knowledge to building firms. Very often, it is only general knowledge for all kinds of business sectors, yet, in some instances the chambers co-operate with trade associations or technical information centres concerning more targeted information to firms in the building sector. For "grass roots" organisations concerned with energy savings and sustainable buildings there are a number of local offices throughout the country.

KNOWLEDGE BROKERS AND TYPES OF COMMUNICATION

In the following, the knowledge brokers are categorised with regards to (1) whether they are knowledge producers or mostly act as intermediaries (or a mixture of both), and (2) the types of communication/dissemination strategies they use. As a starting point, we propose five main types of communication or dissemination strategies:

- *Education*: This category of knowledge communication/dissemination comprises all kinds of education. Education may be the most important and efficient single means of communicating new knowledge in the construction business system, but at the same time education is surprisingly overlooked in the debate on problems of inefficiency in the Danish R&D and innovation system.

- *Consulting*: Consulting comprises all situations where knowledge is directly communicated between suppliers and users of knowledge with the purpose of solving a specific problem. Almost every knowledge broker is supplying consulting services to some extent.

- *Codified knowledge*: Comprises structured and processed knowledge in the form of reports, articles, written guidance, manuals, etc. Codified knowledge also comprises the results from standardisation work and certification schemes.

- *Information services and databases*: All the different types of communication dealing more with information than with knowledge. These services are often supplied as an integrated part of knowledge services, while others are supplied as dedicated information services, e.g. hot-lines, libraries, databases, etc.

- *Networking*: This category comprises dissemination of knowledge through professional associations, formal/informal networks around knowledge producing organisations, development programmes, etc.

Table 1 is showing a preliminary mapping of knowledge brokers with respect to their predominant communication types and strategies.

Table 1: Taxonomy of knowledge brokers concerning their use of different types of communication

	Own knowledge production	Own knowledge production and intermediaries	Mostly intermediaries
Education	Universities Architectural schools	Approved technological institutes Polytechnics, technical training Vocational training Continuing education	Polytechnics, technical training Knowledge Centres Vocational training
Consulting	Producers/ manufacturers	Approved technological institutes Consultants Producers/ manufacturers	Knowledge centres Publishers, web-portals
Codified knowledge	Universities Sectoral research institutes Development programmes Public authorities	Approved technological institutes	Trade and employers' associations Approved technological institutes (standardisation and certification) Producers/ manufacturers Libraries Publishers, web-portals
Information	Public authorities	Trade and professional	Database hosts

services and databases	Libraries	associations	Wholesalers of materials and components Knowledge centres Web-portals
Networking	Universities Sectoral research institutes Development programmes	Approved technological institutes	Trade and employers' associations Trade unions Professional associations

CONCLUSION

In this paper we have identified and characterised the configuration of twelve groups of knowledge brokers in the Danish building sector. We suggest that the methodology for data collection and the typology, presented in this paper, is a useful starting point for cross-national comparisons of the role of knowledge brokers in different institutional settings. Hence, the methodology demonstrated here could form a basis for comparative work as part of the activities of CIB TG47 on "Innovation brokerage in construction".

The overall picture derived from the initial analysis of the twelve groups of knowledge brokers is that of a large, fragmented and dispersed population, which to a large extent seems to reflect the nature of the building sector generally. The overall effectiveness and the existence of common objectives of the building R&D system may be questioned. However, the apparent atomisation of the system and the diversity of brokers can also be interpreted as an important part of the business system infrastructure, which helps building firms in articulating their needs and interests with regards to specific problem or business areas.

With reference to figure 1, where the traditional view of the basic structure of the Danish R&D system is shown, our typology of knowledge brokers can be helpful in broadening the traditional view of knowledge production and dissemination. The linear "downstream" movement which is traditionally focused on, can be supplemented with the observation that various kind of knowledge brokers supply the knowledge producing institutions with inputs from the firms and individuals of the building sector, thereby securing an "upstream" impetus to the R&D system.

In fact, the conceptual model of the R&D system may be extended (in the direction of the lower right corner) by inserting the twelve groups of knowledge brokers into the model and indicating the "up- and downstream" linkages and flows of knowledge. This is a challenging and worthwhile task, which should be pursue in future research projects.

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APPENDIX A: TYPOLOGY AND OVERVIEW OF KNOWLEDGE BROKERS

1. Education, training, courses Universities Technical universities (master and bachelor) Architectural Schools Technical colleges AMU (courses for un-/semiskilled) Continuing education/training for architects and engineers **2. Sectoral research institutes, government laboratories** Building and urban research Energy and environment Building restoration, listed buildings Surveying and cadastre Forest and landscape Safety and health of workers **3. Approved technological institutes** Building technology Energy and environment Fire Acoustics and vibrations Wind and aerodynamics Materials testing Heating and combustion Standardisation Hydraulics Geotechnology	**5. Trade and prof. Organisations** Consulting engineers Engineering professionals Consulting architects, Architectural professionals General, specialist and trade contractors Technical staff Building manufacturers Building suppliers Building, civil and wood worker union Consulting surveyors **6. Libraries/databases** Technical Architectural BODIL, DANDOK ICONDA (international) **7. Public authorities etc.** Electricity European technical approvals for construction products (ETA) Agency for Trade and Industry Ministry of Housing and Urban Affairs Danish counties and Municipalities	**9. Certification, control etc.** Certification schemes for materials and components Control schemes for materials and components Energy consumption schemes and consultants Declaration scheme for buyers of second hand housing Facilities management key indicators Standardisation and specifications Experience-based problems **10. Private companies** Engineering (and architectural) consultants Producers/manufacturing firms Wholesalers **11. Public development programmes** "Project House" "Project New Partnerships" "Project Urban Renewal" Process and Product Development in Building Demonstration projects programme
4. Dedicated knowledge centres Danish Centre for Architecture Ecological building and urban ecology	**8. Client organisations etc.** Ministries of Housing and Urban Affairs, Education, Defence, Research, Culture State building owners (SEF) Co-operative housing	**12. General knowledge dissemination** Insurance and guarantee schemes Safety and health of workers

Traditional building and restoration techniques Winter construction consultants Standardisation and specifications Masonry and brickwork Wood and timber Roofing Flooring Cement and Concrete	Non-profit housing Maintenance and facilities management Building owners Land owners Landlords Tenants Urban renewal companies	Unemployment offices EuroCenter Regional/local trade councils Winter construction consultants Local energy and environment offices Autocad users in building Building information centre Building defect funds Network for research institutions Technical information centre network Danish Centre for Architecture Ecological building and urban ecology Academy for Technical Sciences Building Development Council

Comparative Study of Design-Build Procurement between Japan and the US on Risk Management Approach

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ABSTRACT

The Japanese construction industry has a few procurement selections, Design-Bid-Build and Design-Build. It is however quite different from Design-Build of US definition. In the US, Design-Build is used as one of some procurement selections, which clients focus on a single responsibility to their project. Even though the Japanese Design-Build by large general contractors is applied to all types' clients and has a reputation of high quality, advanced technology, but there is only one standard contract for Design-Bid-Build, which avoids to define the Japanese Design-Build. There are many differences of Design-Build definition between two countries.

This paper therefore makes a clear definition for the Japanese Design-Build as a good partnering procurement selection for the Japanese clients, in order to improvement of the Japanese Construction industry, which is based on comparative study of Japan and the US Design-Build procurement.

INTRODUCTION

"Toh-ryo", Master Builder in Japanese, who has the both functions of the designer and the contractor, has traditionally carried out the construction works in Japan. This is not a unique phenomenon in Japan. You can imagine the ancient construction works, such as the Parthenon. The head person who carries out design and construction has been called "the master builder" in the western country. It is, therefore, natural that the Western and Japanese Design-Build (DB) have the same origin by their historical background. However, the Design-Build in the western countries, especially in the US differs largely from the Design-Build of Japan, from the viewpoint of organisation, the range of risk management.

The purpose of this research is to perceive the procurement selection of Japan and the US by comparing and examining each characteristic.

The Design-Build in the US, which is one of procurement systems such as Construction Management (CM), Project Management (PM), Design-Bid-Build (DBB), is carried out by the result of client's requirement, considering the client's experience of construction projects, economic factor and so on. There are some aspects that the Japanese DB has the similarity as the western DB procurement, which the DB leaves certain degree of client's risks to the contractor. However, it is the fact that the definition of the Japanese DB is not quite similar to that of the US from the viewpoint of risk management and contract system. The Japanese DB has the strength from the viewpoint of client's risk rather than DB in the US. But, the Japanese DB is not understood to the other countries, even though there are some possibilities to progress the procurement system as one of best selection. The problem is that we do not make clear definition on contract and clear role to all project participants. That is uncertainty on the Japanese contract. We called here that is the Japanese Partnering. This paper makes it clear that the Japanese DB is client's oriented procurement rather than the US DB, even though there is some uncertainty. The Japanese construction industry has the necessity to introduce risk management without uncertainty to the contract system as best practices of the DB in the world.

RISK MANAGEMENT

Definition of risk

"Risk" is able to estimate the possibility of certain phenomenon and prediction; we do not treat "risk" which is uncertainty.

It is not necessarily said that the risk minimum is not equal to the cost minimum or the best value. Figure 1 shows that the best value in the PFI (Private Finance Initiative) in the UK is not risk minimum. The point

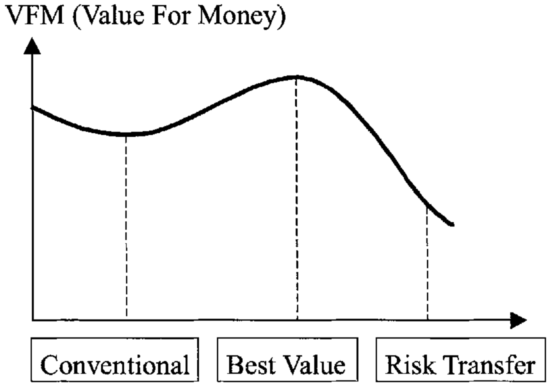

Figure 1 VFM in the PFI

of best value is that client accepts, not risk free, but some certain degree's risk. It is simple that some extent of risk acceptance will produce some expected value for profit.

Risk is, basically, able to analyse statistically and estimate the degree of appearance. For instance, the probability of rain can be estimated based on the past rainfall data, which is called "risk". "Uncertainty" is, on the other hand, impossible to find out expected value and it is not concerned to the "risk", in other words, "uncertainty" is expressed as " transparent" and "non-transparent". As shown figure 2, "risk" is not fluctuating by the degree of uncertainty. This paper treats not "uncertainty" but "risk".

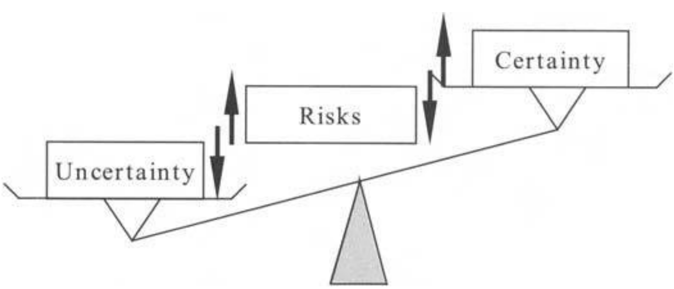

Figure 2 Differences of Risk, Uncertainty, Certainty

Risk allocation

Hartman & Snelgrove (1996) carried out survey regarding the risk allocation between contractor and client. Table 1 shows the risk and risk allocation of each participant. Clients feel that there are a lot of risks to quality, which causes disputes between them. On the other hand, contractors have the feeling to receive the risk regarding payment and cost rather than clients.

Table 1 the risk allocation in a Lump-sum contract

Ran k	Owners	Contractors	Consultants
1	Disputes	Payment	Inspection
2	Inspection	Other Contractor	Changing work
3	Instruction	Authority of consultant	Other contractor
4	Owner's rights	Inspection	Instruction
5	Review of work	Rejection of work	Payment
6	Payment	Mutual responsibility	Rejection of work
7	Authority of consultant	Subsurface condition	Temporary structures

THE CHARACTERISTIC OF THE DESIGN BUILD IN THE US

Present condition and future Design-Build

It would make sense to assume that the DB in the US as one of the variety of procurement selection is not equal to the DB in Japan by a general contractor, so called the Japanese General Contractor (GENE-CON or ZENEKON in Japanese) which means that one company hire both architects and contractors with advanced research institute, having single responsibility for construction projects.

Table 2 shows that Design-Build Institute of America (DBIA) estimates the market share of each procurement method. DBIA is expected to increase DB in the US market. It is, however, an important fact that the main procurement in the US is Traditional procurement method rather than DB, CM and others. This situation is quite different from the Japanese construction industry, which is dominated by only two kinds of procurement methods that are both DB and Design-Bid-Build.

Table 2 Market prediction of the DB by DBIA

	1987	1997	2006
CM at Risk	8%	10%	10%
Design-Build	3%	25%	45%
Design-Bid-Build	88%	65%	45%

This difference between the US and Japan has been mentioned by the real business cases as shown Table 3. It is nevertheless to say that the market share of DB procurement method in the US is not high in comparison with that of CM.

Table 3 Major procurement by some big contractors in the US

(Unit: one million dollars)

Company	DB (1995)	CM at Risk (1995)	Total amount of receiving value (1995)	DB Ratio (1995)	CM Ratio (1995)	CM Ratio (1996)
Centex Construction	68.6	389.2	2968.7	2.3%	13.1%	14%
The Turner Corp.	99.7	2627.3	2727.0	3.7%	96.3%	94%
The Clark Construction	253.0	0	1485.0	17.0%	0%	0%
Gilbane Building	-	1000.3	1370.5	-	73.0%	43%
Bovis Inc.	128.2	507.2	1277.2	10.0%	39.7%	47%

(Source: Engineering News Record (1996)

An adequate project for Design-Build

Songer (1997) studied about the characteristics of typical construction projects in the DB by surveying 137 US public clients. The result is shown as Table 4.

Table 4 Preferable conditions for Design-Build

Characteristics of Design-Build	Mean	Rank
Well defined Scope	5.41	1
Shared Understanding of Scope	5.22	2
Owner's Construction Sophistication	4.62	3
Adequate Owner Staffing	4.57	4
Established Budget	4.35	5
Established Completion Date	4.16	6
Availability of Design-Builders	3.79	7
Willingness to forego Design Input	3.78	8
Owner's Risk Aversion	3.72	9
Standard Design Specifications	3.56	10

Furthermore, 15 representative projects were surveyed. As the result of it, the next 5 points were recognised as the characteristics of the DB in the US.

1. Scope of works is evident between client and contractor.
2. Mutual understanding is essential for establishing the scope of works.
3. A client is familiar to the construction project.
4. The appropriate client staffs are arranged.
5. Budget is established before starting a project.

Public clients' attitude to the Design-Build

Molennar (1998) studied to set the criteria of the DB by the surveys of 122 public clients. The selection standard of the DB by public clients is classified into the next 5 categories which is similar to the procurement selection proposed by the National Economic Development Office (NEDO) in the UK as shown in Table 5, which adapts Multi-attribute Analysis. Molennar's suggestion can be accessed on the Internet website (http://www.Colorado.EDU/engineering/civil/db).

1. Budget variance
2. Schedule variance
3. Conformance to expectation
4. Administration burden
5. Overall user satisfaction

Table 5 The characteristics of the procurement selection of NEDO in the UK.

Client's requirements	Tr	DB	MC	CM	DM
TIME	10	90	100	90	80
COST	90	100	20	30	20
Flexibility	100	30	80	60	70
Complexity	40	10	100	70	80
QUALITY	100	40	100	50	60
On TIME	50	90	90	100	90
Within Budget	30	100	60	90	90
Single Responsibility	30	100	10	90	90
Professional Responsibility	100	10	100	30	30
Risk Transfer	30	100	10	100	80

Tr: Traditional Procurement
DB: Design-Build
MC: Management Contract
CM: Construction Management
DM: Design and Manage

Further analysis makes some suggestions to the definition of DB that the scope clarification is essential to proceed DB. The DB is not adequate for the Japanese "entrust" order with huge uncertainty but the high transparent project with scope clarification that is able to calculate the project risk.

Some typical opinions to the DB by the US public clients are as follows, according to Mollenar's survey.

The clarification of the scope is the most important thing. (The scope clarification produces reduction of the project cost shortening the construction schedule.)

The more design stage makes progress, the more difficult DB entity make proposals for design.

Better proceeding in the DB depends on how much RFP (Request for Proposal) with detailed and cleared scope of works has been made.

Before design stage, clients set clear budget and clients' aggressive involvement to project.

It is generally considered that the DB is adequate for simple construction projects rather than complicated projects in the US. But now, situation has been changed to adopt the DB to the complicated projects in the US public sector because of decreasing in-house stuff.

Risk in each procurement method

Risk is defined the result of procurement selection between clients and contractors. For instance, the DB has much more risks for the contractor than that of CM.

However, higher risk does not mean high cost, but minimum cost. Because it is general economic theory that, if you take a big risk, you get much more money or lose your money than you expected.

It is good thing to know the extent of risks for the client in order to select the procurement systems. In the DB, contractor accepts more risks than the client, which brings a great benefit to the contractor. But it is not necessary to make a further payment for the client because of the fixed price in the DB.

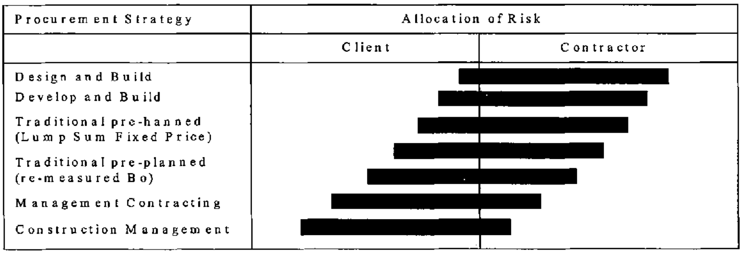

Figure 3 Contract Strategies and the balance of risk (Source: CUP (1993))

DESIGN BUILD IN JAPAN

SAITO (1999) reported that the DB in Japan is the result of the confusion between risk and uncertainty. SAITO also makes points of some characteristics in the Japanese DB as follows.

1. Client has the decisive power of the budget and there are no requirements for the project except the budget.

2. The scope of works has not been indefinite before starting a project.

3. The Japanese DB is adapted to all kinds of construction projects, from small projects to large-scale developments.

4. The DB is sometimes used in order to transfer risk from contractor to client, which the contractor gets much more revenue in stead of losing money in the previous project under a long-term relationship.

5. In public projects, it is rare to use the DB. A few challenging projects have been applied.

6. There is no standard contract for the DB in Japan.

In view of the relationship between cost and risk, the analysis of contractor's organisation and client's attitude is essential to understand the Japanese DB.

Relation between the risk and cost of the Japanese contractors

The relation between risk and cost in Japanese projects are classified in the following types.

1. The risk of each construction project has the similarity. (The relation between risk and price is constant.)

2. The risk depends on the characteristics of construction projects. (The construction cost has become much higher, if the contractor accepts much more risk than the client.)

Figure 4 and 5 shows the case that the relation between risk and cost is constant. Every project, even a small project, has the same risk ratio so that every client pays the fee for avoiding risk equally. In other words, even client for having a little risk pay some fee for recovering the risk. The client who is taking high risk is able to pay less money than what he has to compensate.

However, Figure 6 shows the result of client's cost by each client's risk share. In this case, risk lover receives high risk and high profitability or huge deficit than risk avoider.

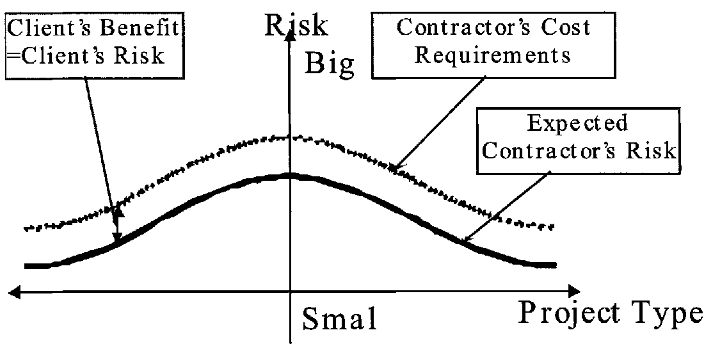

Figure 4 Low-risk projects

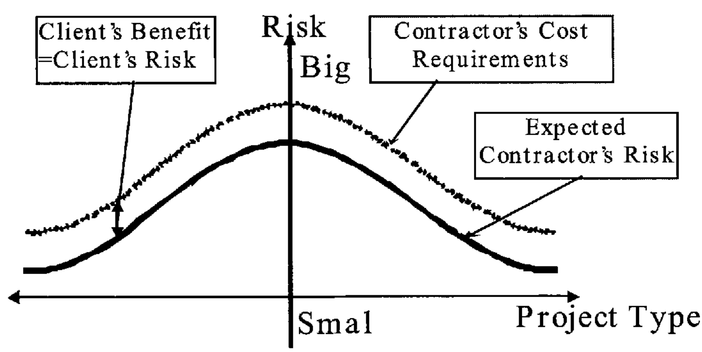

Figure 5 High-risk projects

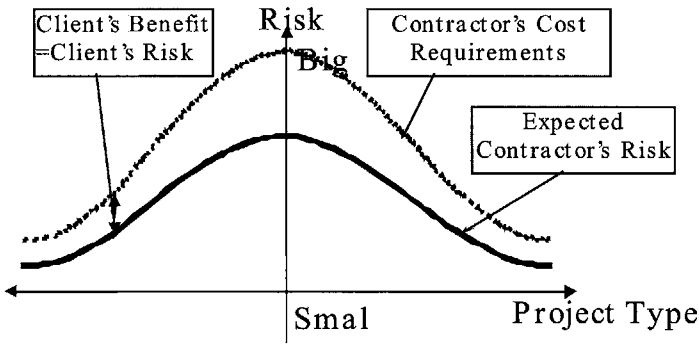

Figure 6 Linear relations between risk and cost

Classification of the contractor's organisation in Japan

The strength of the DB in the US is to take the constructability and buildability with great knowledge of construction process and information. The contract documentation is essential to carry on the constructability and buildability. However, as mentioned before, there is no standard contract of the DB in Japan. The Japanese General Contractor (GENE-CON) is categorised into the following three types' organisation structure.

1. The same organisation or company carries on both design and construction. (Constructability has become effective at design stage by the result of feedback of design and construction information)

2. The separate organisation or division even in one company progresses design and construction separately. (This case is the same as Design-Bid-Build organisation that architect is requested to make a design within budget only, without introducing constructability and buildability.)

3. Design and construction is separated, but management process between design and construction is unified as one company. (As one company, there is the system that construction side's suggestions are induced to the design process.)

Although the operation unit like the organisation, which controls both design and construction as a team, is desirable for the DB procurement method, the Japanese client does not always require the same organisation for the designers and contractors. Because some clients require the separate organisation in order to clarify the responsibility for design and construction.

The Japanese contractor makes their organisation to adopt both two requirements. One is that the same organisation carries on design and build, the other is that, even in one company, different team progresses design and build separately. The Japanese contractor answered to each client's requirements by partnering.

Attitude of the Japanese client

The Japanese client requests various services to the construction project service like European clients. There are also a variety of construction projects and clients from entrusting the contractor to having the in-house project manager.

Diversity of the client is, for example, as follows.

Indefinite Scope of Works ⇔ Clear definition of Scope

Indefinite Budget ⇔ Clear budget

Indefinite project's duration ⇔ Clear duration

Large burden to the client side ⇔ Small burden to the client side

High customer satisfaction ⇔ Low customer satisfaction

As shown table 6, the Japanese construction client selects a variety of procurement methods. It is said that the Japanese construction industry has already served enough procurement selection for the client.

Table 6 Procurement structure in Japan (1994)

Company	Design-Build (million yen) (A)	Total amount of receiving (Million Yen) (B)	Ratio of Design-Build (A)/(B)*100
Takenaka	796,945	1,448,692	55.0%(61.0)
Shimizu	657,564	1,564,761	42.0%(47.4)
Kajima	491,778	1,283,451	38.3%(42.1)
Taisei	486,130	1,267,886	38.3%(49.3)
Obayashi	465,805	1,055,746	44.1%(50.5)
Average	579,644	1,324,107	43.8%(50.1)

Problems of the Japanese Design-Build

Previous section is able to show the analysis of typical DB organisations and procedures. However, the problems of the Japanese DB are that the client has a little selection in order to carry on his own construction project, because the contractor receives all responsibility even what is considered the client's responsibility.

The main reason of lack of selection for the client is as follows.

1. There is no standard contract to promote the DB procurement method.
2. The procedure of DB cost estimation is quite different from that of Design-Bid-Build. For instance, total cost is estimated by contractor without completed design drawings.
3. The project quality is only defined by drawings.
4. Unit price is not clear in the DB, because of lump-sum contract.

Relation between client's risk and contractor's risk

The client's risk and contractor's risk should be allocated as the result of the degree of risk permission by negotiating with the client and the contractor, which decides the total project cost.

Figure 7 shows the concept of client's risk and contractor's risk. The vertical axis shows the construction price. Each curve shows the risk characteristic in a certain project. The point "O" is the ideal point that the acceptance of client's risk is equal to the proposal of contractor's risk. Also, this point corresponds to the result that each client and contractor makes a contract at the price that they confirmed.

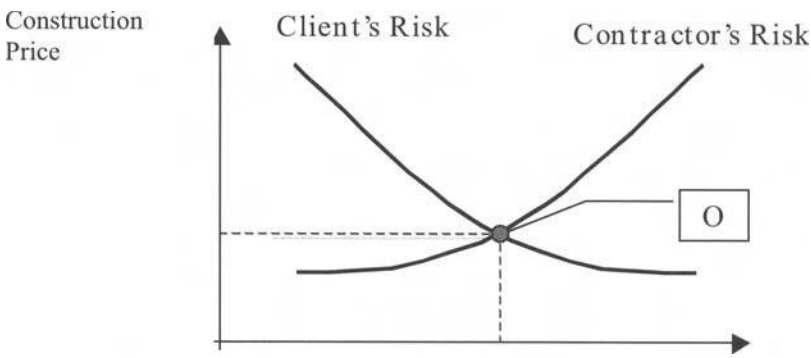

Figure 7 Client's risk and Contractor's risk

Figure 8 shows the result that client clarified his scope of a construction project in order to decline the project price. While the point "O" in the figure 7 is stable point, point "A" in the figure 8 shows that the clarification of risk and scope for the client decreases the construction cost. However, contractor has received much more risks than stable point like point "O" because of allowance of uncertainty in the Japanese construction industry. This situation does not occur the risk transfer

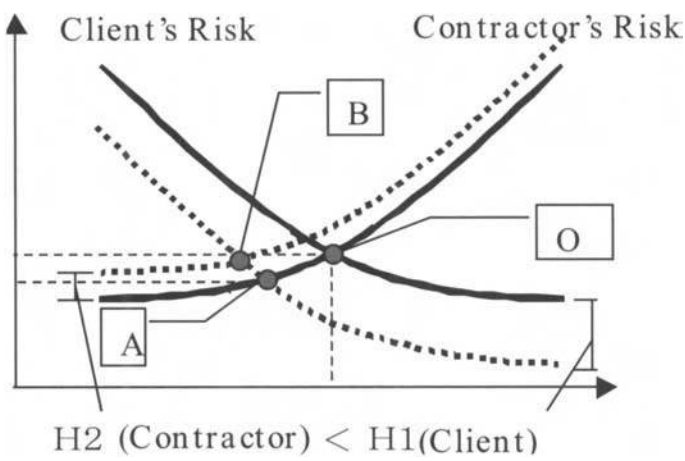

Figure 8 The Japanese Design-Build

easily. As the result of that, client is not able to transfer the risk to the contractor. After that, if client makes clear his scope, the incentive for cost deduction has not occurred, but rigidity of cost has occurred. Even the client makes some suggestions to decrease cost such as the clarification of his requirements, which is not useful. The point "B" shows that cost of DB does not decrease under any circumstances.

Because, the differences of contractor's risk avoidance is very little to the point "A"&"B".

Figure 9 shows that the curve of contractor's risk acceptance is sensitive to the price and cost, so that client's risk transfer has happened easily. The characteristics of the DB in the US and UK is understood that clear scope of works to the DB is able to reduce the construction cost.

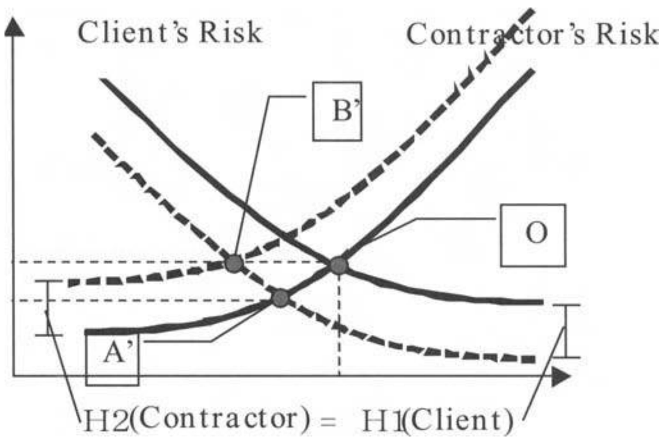

Figure 9 the Design-Build (US)

In the comparison between the Japanese and the US DB, the Japanese DB has the rigidity to control the construction cost because of contractor's weak risk acceptance.

Definition of the Japanese Design-Build

DB is defined in general as following assumption.

$$F(x) = Risk(x1) \times Organization(x2) \times Cost(x3) \tag{1}$$

(x: client's selection、 characteristics of construction projects)

↓

Design-Build (TYPEI、 TYPEII、 TYPEIII、 ···)

The characteristics of the Japanese contractors are that they hire architects and researchers in their company, that this system is adequate for a variety of clients. Moreover, the Japanese General Contractor (GENE-CON) has the evaluation that

Constructability and Buildability are carried out easily by their strong technological power.

Risk allocation method in the Japan is similar to the US and UK procurement system from the view point of contractor's responsibility, that the contractor serve a wide range variety service to the client with high flexibility for each project style.

The Japanese DB has the strength that there are a variety of contracts and procurement systems, even only one DB procurement by the wide adaptations of one contract.

But, there is the problem that, not the client, but the contractor decides the construction method and procurement method. It is therefore necessary to introduce clear definition and explanation to the client in order to satisfy the client's requirements. Furthermore, risk management in the Japanese construction projects is one of the best solutions to improve uncertainty condition of the project.

DIFFERENCES OF CLIENT'S REQUIREMENTS BETWEEN THE US AND JAPAN

Table 4 shows the utility score of the reason why clients select the DB procurement method in the US, which is based on the 182 questionnaire results by Songer (1996). The utility score of Japan was calculated by using Multi-Attribute Rating Technique by Saito (1994). According to Table 4, the higher requirements in the US clients are early completion, fixed price and clear responsibility among participants. However the Japanese DB has many kinds of risks for the client except fixed price contract.

Table 4 The characteristic of the procurement method

Client Requirements	US	RANK	Japan	RANK
TIME (Early Completion Required)	0.147	1	0.098	6
COST (firm Price)	0.147	1	0.148	1
Flexibility (Variations Necessary)	0.044	9	0.066	9
Complexity (Advanced Technology Necessary)	0.029	8	0.066	9
QUALITY (Important)	0.059	7	0.115	2
Certainty (On Time)	0.147	1	0.115	2
Certainty (Within Budget)	0.147	1	0.082	7
Single Responsibility	0.147	1	0.115	2

Professional Responsibility	0.015	10	0.082	7
Risk Transfer	0.118	6	0.115	2

It is expressed with the following formula, when the client demand, which is satisfied on the basis of the contract method of Japan and the US, is higher than the expected value.

Value (i)= Σ Ki*Vi (Ki: Utility, Vi: Procurement) **(2)**

If the Japanese DB is applied in this formula, Value (JAPAN) has become as follows, because only the cost factor is defined, but the other factors are indefinite.

Value (i) ≒ Value (JAPAN)=0.15*V **(3)**

It becomes, however, as follows, when the DB of US is applied

Value (US) ≒ Σ Ki*Vi>(0.15*Vi)*4> Value (JAPAN) ≒ 0.15*V+0.12*Vi*2 **(4)**

This equation shows that the US DB has the possibility to be much more Customer Satisfaction procurement method than the Japanese DB.

Figure 6 shows that the US DB is adequate procurement method for a variety of construction clients because of clear definition to control project risks. On the other hand, the Japanese DB is good for the clients who avoid all his own risks even though the project cost has become high. In other words, the Japanese DB has not become adequate for all types clients because there are uncertainties of projects.

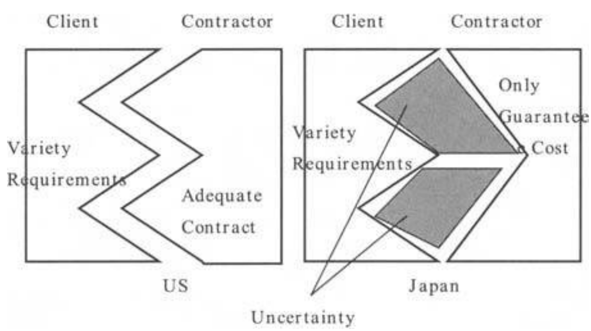

Figure 10 The Difference of Contract between the US and Japan

IMPROVEMENT FOR THE DESIGN BUILD IN JAPAN

"RISK" is able to forecast the possibility of what it happens. After the result of risk definition in construction projects, the construction client can select the most adequate procurement method by his own risks, which is indicated by the contractor.

The Japanese DB has the strength that a great variety of clients can carry on their construction projects with wide flexibility. As far as contractors keep their responsibility whenever they avoid all risks, the Japanese DB is the most beneficial procurement method for those kinds of clients.

However, problem exists that only contractor can select the procurement method. The client has no selection for contractual system. Furthermore, only contractor has whole information to the project, which is not clarified to the client. That means all information and risks are concealed to the client from contractor.

It is necessary to introduce the risk management approach for the Japanese contract and procurement method in order to achieve high quality and plenty of customer satisfaction. Moreover, the decision for risk attitude should depend on the clients' selection. The Japanese DB, which consists of design, specifications, contracts, should be re-examined from the viewpoint of risk management. As the result of it, clients will have a wide range of procurement selection. In near future, the Japanese style partnering will be improved to take forward for clients by introducing risk management approach to their construction projects.

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Theme 5: Quality Improvement & Safety in Construction

Innovative Approaches for Improving Safety in Construction Work Zones

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ABSTRACT

Maintaining traffic flow and safety of motorists and construction workers in rural Interstate work zones are a major concern for state Departments of Transportation (DOTs). In order to reduce the frequency of crashes occurring in these work zones, many traffic agencies have implemented different technologies to provide road users more information of the dangers that lie ahead.

During the period April to November of 2000, Interstate 65 (between Indiana SR-26 and Indiana SR-43) in Indiana was the site of several accidents. In total, 92 accidents and 4 fatalities occurred in this 6-mile rehabilitation project. On average, the work zone experienced 3.3 wrecks per week during the 6-month duration of the project. The accidents occurred, despite the use of 60 warning signs, 5 message boards and 3 arrow boards. In addition, over 1500 citations were issued for speeding violations. The consensus among transportation officials is that driver awareness must be improved by providing more effectively communicating information of the upcoming workzone.

The purpose of this paper is to give an overview of traffic management technologies that are currently implemented for enhancing the safety in interstate work zones. It will outline the characteristics of each system, the main components and the current status of the techniques.

INTRODUCTION

Maintaining traffic flow and safety of motorists and construction workers in Interstate work zones are major concerns for DOTs. The vast majority of the necessary construction work is performed with high exposure to existing traffic. In addition, delays, long queues and lines of halted vehicles tend to be a typical and growing irritant for road users traveling through workzones. It is imperative to find ways by which safety can be improved in construction work zones, specially, since there is an increasing volume of rebuilding and maintaining of existing highway infrastructure, in addition to new highway construction in the United States.

Increased federal and state funding has prompted an increase in highway construction activity. Accidents tend to increase when there is an increase in construction activity, as evidenced in recent years. In order to reduce the frequency of crashes occurring in these work zones, traffic agencies have implemented different technologies to provide road users with more information of the dangers that lie ahead. The consensus among transportation officials is that driver awareness must be improved by providing more effective information of the upcoming roadwork.

Several States with the Same Problems

During the period April-November 2000, Interstate 65 (between Indiana SR-26 and Indiana SR-43) in Indiana was the site of several accidents. The project consisted on bridge rehabilitation on an existing rural 4-lane median divided highway with a typical average daily traffic (ADT) of 40,000 vehicles per day. In total, 92 accidents and 4 fatalities occurred in this 6-mile rehabilitation project. On average, the work zone experienced 3.3 wrecks per week during the 6-month duration of the project. Indiana is not the only state where such problems have occurred. Illinois experienced similar accidents on Interstate 74 between St. Joseph and Danville, IL near a construction work zone.

In an effort to reduce the accidents near a construction work zone, the Indiana Department of Transportation (INDOT) initiated a study for Improving Construction Work Zone Safety. The objectives of the project are to (a) determine if it is appropriate to consider temporary roads and bridges during construction activity, and (b) to evaluate if improved signing or active warning devices have an influence on work zone safety. This paper describes the research in progress. In particular, it will give an overview of the of portable traffic management devices that are currently implemented for enhancing the safety in interstate work zones.

BACKGROUND OF TRAFFIC MANAGEMENT TECHNOLOGIES

What is a Work Zone?

Until recently there was no nationally recognized definition of work zones. According to Turner (1999): "A work zone can be defined as an area of traffic way with highway construction, maintenance or utility-work activities. Signs, channeling devices, barriers, pavements markings, etc, typically mark a work zone.

It extends from the first warning sign or flashing light on a vehicle to the “End of the Road Work” sign”.

In work zones, motorists can encounter delays, lines of halted vehicles and long queues. Delays in work zones must be kept to a minimum to ensure safety of personnel, road users and to minimize the probability of accidents. Unfortunately, accidents have occurred and no state is immune to this type of incidents. In the I-65 project in Indiana, despite the use of 60 warning signs, 5 message boards and 3 arrow boards a total of 92 accidents and 4 fatalities occurred. In addition, over 1500 citations were issued for speeding violations.

TRAFFIC MANAGEMENT TECHNOLOGIES

Description of Characteristics

In order to analyze and compare different technologies the system characteristics must be taken into consideration. The factors considered in the analysis include: *Need*, *Methods to Transmit Information*, *Information to be transmitted*, and *Deployment.*

The Need describes the purpose of development for each traffic management technology. The factor *Methods to Transmit Information* includes the type of detection devices currently used by each technology and the types of remote administration capabilities of the different technologies. The factor *Deployment* addresses previous, current and past projects that have adopted each technology.

Research Methodology

The identification of different traffic management technologies and their analyses was based on a comprehensive literature review, discussions with the developers of each technology, site visits and discussions with engineers and personnel of various Departments of Transportation. The following sections provide a brief insight into the several traffic management technologies analyzed thus far.

AUTOMATED INFORMATION MANAGEMENT SYSTEM (A.I.M.S.)

Need

To reduce driver frustration, it is important to inform drivers of what lies ahead, expected travel times, and also of alternative routes. AIMS developed by United

Rental Traffic Division, Mechanicsburg, Pennsylvania provides drivers with continuously updated information about travel times, vehicle speeds through a work zone, and even alternative routes that can be used to avoid delay.

Methods to Transmit Information

AIMS is an algorithm designed to provide continuous monitoring of interstate traffic for improving safety. The software collects traffic data from current traveling conditions typically through the use of microwave sensors as detection devices. However, other types of detection devices such as radar detectors can also be used for data collection. Traffic data collected by the sensors is transmitted to a central base station were the AIMS algorithm processes the data and relays informational messages to motorists by means of Variable Message Signs (Figure 1), Highway Advisory Radio (HAR) and also through the use of Alert Beacons. AIMS can also relay information about the roadway conditions to Department of Transportation officials by means of video, website, or though the use of pagers. The public can also gain information about the roadway by accessing a website designated for the construction project and viewing the messages displayed to motorists.

Information to be Transmitted

AIMS can inform motorists approaching the work zone of vital information such as a speed reduction that lies ahead and the location of an accident that has occurred. Besides these crucial messages, AIMS can also display to motorists the level of congestion of the roadway, the degree of enforcement activity that has occurred in the work zone and other warning messages that are necessary.

Figure 1: AIMS VMS Message

Deployments

The Automated Information Management System has been deployed in several states. The state of Pennsylvania deployed AIMS on the Pennsylvania Turnpike near exits 13 through 15. AIMS has also been used by the state of Illinois in two locations. During the Winter of 2001, AIMS was deployed on a construction project on I-55 near Springfield, IL, and it will remain active until the fall of 2002. Several more deployments, including two in Illinois are anticipated for the 2002 calendar year.

ADVANCE SPEED INFORMATION SYSTEM (ASIS)

Need

Vehicular speeds before and through work zones vary significantly and drivers may sometimes not have sufficient time to react when they are involved in a rear-end collision. ASIS (Advance Speed Information System), developed by PDP Associates, Cincinnati, OH, is a condition-responsive technology designed to provide real time information to road users about the vehicular speeds throughout several points upstream of a work zone. The purpose of this technology is to reduce the number of rear end crashes and minimize surprises to drivers approaching stopped or slowed traffic.

Methods to Transmit Information

ASIS deployment consists of equipment, which is mounted on variable message signs. ASIS has two separate models available to the public. Both models can consist of as few as two message boards or as many message boards as is desired by a DOT. The Basic System runs autonomously without any central control. No indication is given to the owner if a component fails. The advanced system has the feature of central control (Base Station). The owner is notified in the event of a failure of one of the components. More messages are available for this system than the Basic system. The Advanced System, unlike the Basic System, has the ability to store traffic data if required.

ASIS can be described as an extension of the Travel Time Prediction System (TIPS) technology, developed earlier by the company. In a typical configuration, ASIS utilizes side-fire microwave detectors, similar to TIPS. The information is transmitted to motorists mainly by using Variable Message Signs (VMS) located throughout each approach of the workzone. Mounted or incorporated on each VMS, a traffic sensor, a micro controller and an antenna are integrated.

Information to be Transmitted

ASIS displays actual vehicular speeds at upstream points on a highway. The vehicle speeds are calculated as vehicles pass a sensor and are stored in holding bins with a unit of time specified by the user. Separate holding time is used to delay the changing of the message. The speed is updated on an upstream message board when this holding time is over. This sequence is repeated and the information received by the sensor is displayed (Figures 2 & 3) to the motorists on the upstream locations of the work zone. The information can be displayed by following different formats specified by the DOTs. In addition to displaying the information on VMS, the information can also be transmitted by using the Internet.

Figure 2: ASIS Message Displayed # 1

Figure 3: ASIS Message Displayed # 2

Deployments

Since ASIS is a new technology, as of January 2002, ASIS has had no deployments. This technology is planned for deployment in the upcoming construction seasons.

COMPUTERIZED HIGHWAY INFORMATION PROCESSING SYSTEM (CHIPS)

Need

The need of a technology that incorporates infrared queue length detectors to determine when traffic has slowed below a threshold or has completely stopped, led to the development of CHIPS (Computerized Highway Information Processing System) by ASTI Transportation Systems, Inc, New Castle, Delaware. CHIPS is a real-time system to improve highway safety and reduce work zone accidents by providing motorists information about the expected conditions on the Interstate.

Methods to Transmit Information

CHIPS is an algorithm designed to provide continuous monitoring of interstate traffic for improving safety. This technology stores different traffic data of current traveling conditions by utilizing microwave sensors as detection devices. The information is transmitted to motorists by means of Variable Message Signs, blank-out fiber optic signs, Highway Advisory Radio (HAR) and ramp metering. In addition, a Wizard CB radio was used in a project on Arkansas on I-55/I-40 to inform drivers of halted vehicles and road conditions further downstream.

Information to be Transmitted

CHIPS benefits motorists through improved safety by providing accurate and credible advisories of current traffic conditions. This technology was developed to provide road users of warning and advisory messages. In addition, the DOT can specify if alternate routing and dynamic speed alerts are desired. CHIPS was developed to run autonomously and can be easily modifiable to adjust the condition required during a long-term construction project.

Deployments

This technology was deployed in the state of Pennsylvania. Current deployments of CHIPS include the Arkansas project (I-55/I-40) several projects in Delaware and a project near Rochester in New York.

TRAVEL TIME PREDICTION SYSTEM (TIPS)

Need

Messages displayed in Variable Message Signs (VMS) can sometimes be ambiguous and somehow confusing for motorists. Most available traffic management technologies display delay in the upcoming segment of road construction. The developers of TIPS (Travel Time Prediction System) believe that delays must not be displayed because it is too vague of a term. Delay requires a reference point that is not common to all users of the roadway. Travel time, on the other hand, is assumed to be understood by all. TIPS is an automated technology developed by PDP Associates that calculates and displays on VMS the travel time in advance and through work zones.

Methods to Transmit Information

TIPS typical deployment consists of one PC, located on a central station (mainly in the field office trailer), which analyzes the data. After investigation of different available detection devices, the developers of TIPS determined to operate the system by using side-fire microwave detectors

Most of the traffic management technologies analyzed has been developed by utilizing software with an intelligent algorithm using an open-end architecture. By doing so, these traffic management technologies are designed to readily accept the incorporation of different "technologies" to provide additional information to motorists. TIPS for example, can use the Internet to display 24-hour road information by using a dynamic web site posted on the responsible DOT domain or on an individual project web site. In addition, highway advisory radio (HAR) can also be integrated in the system configuration to transmit information.

The developers of TIPS have also envisioned providing the real time information near project work zones and in other facilities to establish a proactive approach to transmitting information. Monitors can be located in rest areas, commercial and tourist attractions to facilitate the planning and if possible give drivers the opportunity of finding an alternate route to avoid the congestion through the work zone.

Information to be Transmitted

TIPS displays calculated travel time in advance of and through work zones. By providing motorists with accurate information, decreases the probability of accidents near a construction work zone (Figure 4). TIPS, does not use actual vehicle speeds to determine travel time. Travel times are *calculated* as vehicles pass the sensors. Once they are detected by the sensors, the travel times are collected in holding "bins" with a storing time specified by the user. Travel times are not instantly displayed because they can change from one vehicle to the next. A separate holding time is used to delay the changing of the travel time message. Travel time is updated on the message boards when this holding time is completed (Figure 5).

Figure 4: TIPS Message Displayed # 1

Figure 5: TIPS Message Displayed # 2

Deployments

The Travel Time Prediction System has had three deployments. TIPS was deployed during the summer and fall of 2000 on a 13-mile segment northbound of Interstate 75 in Dayton, Ohio. In 2001 TIPS was deployed again on Interstate 75 in Dayton, Ohio and Interstate 94 near Milwaukee, Wisconsin. Several deployments are pending for the 2002 construction season.

An independent evaluation of TIPS was completed by Helmut Zwahlen (Zwahlen 2001) of the Ohio University for the 2000 Dayton, Ohio project. The most important findings of the evaluation concluded that about 88% of the actual times recorded for each sign, and for all the signs combined, were within a range of ± 4 minutes of the predicted time. In addition, based on anecdotal data obtained by sending a questionnaire to approximately 3000 motorists recorded to be traveling the work zone when TIPS was deployed, 97 % of road users surveyed (with an approximate 20 % response margin) found the system to be helpful and effective in providing travel times.

WORK ZONE ALERT AND INFORMATION RADIO (WIZARD)

Need

A high percentage of accidents occurring near work zones involves rear-end collisions. Commercial Vehicle Operators are involved in most of these types of collisions. Approximately 25 percent of the 719 of the work-zone fatalities in 1996 involved large trucks (Turner 1999). The Wizard Work Zone Alert and Information Radio patented by Highway Technologies, Inc. is designed to give drivers of heavy trucks enough advance warning of upcoming delays at construction sites or incidents to enable them to stop safely before encountering lines of halted vehicles (Kamyab A. Et. Al (2000). The Wizard CB Alert System was developed and patented by Highway Technologies, and built and marketed by TRAFCON industries.

It was originally developed at the request of the Pennsylvania Department of Transportation as a response to problems on a major construction project during 1993 construction season. A high number of accidents and fatalities occurred in this 12-mile length project. Most of the accidents involved trucks (18-wheelers) crashing into slow moving vehicles (Sesny 2001). Although the Wizard is not exactly a traffic management technology, it has been analyzed because a combination of this technology incorporated with any other of the condition-responsive technologies can offer invaluable information to truckers and drivers in general.

Methods to Transmit Information

Many of the traffic management technologies analyzed have remote administration capabilities, i.e., they run autonomously on a 24/7 basis. The Wizard is remote in the sense that it can be activated on/off by a pager. Operators dial a call number and the system "remotely" is switched on/off when desired with capability of storing three messages. The goal for future prototypes of the WIZARD is to obtain a total microprocessor control technology product that can be fully activated by detectors.

The Wizard CB alert system automatically broadcasts an alert message over a CB channel (Channel 19) to warn drivers of traffic or road conditions ahead. The system can record up to three different messages and transmit over two different CB channels. Messages can be either static (three selectable messages) or dynamic (changed by an operator). The system components include a standard CB-antenna with a guaranteed broadcast range of one-to-two miles. It can be either solar-powered or one can use a 12-volt power source. The transmitting interval can be selected by the responsible DOT to three different interval alternatives: 30, 60, and 90 seconds.

Information to be Transmitted

The Wizard is a portable, lightweight device (Figure 6). This radio system can be used as part of a static long-term work zone project mounted on a two-wheel trailer. It can also be used as a powerful portable tool used for service/maintenance operations (such as painting crews) on Interstates for improving safety and minimizing collisions to the trailing maintenance vehicle. Because the CB radio can be modified by an operator (interestingly, female voices have been reported to be more effective), the information to be transmitted is very wide in scope. DOTs have implemented the Wizard for several purposes during construction on interstate work zones. The most significant are: incident location, warning messages, advisory messages and speed reduction ahead.

Figure 6: WIZARD System Configuration *(Source: MwSWZDI 2000)*

Deployments

The most relevant of the previous deployments of the CB Alert system were in Iowa, Kansas and Missouri as part of the Midwest States Smart Work Zone Deployment Initiative (MwSWZDI). The system was effective on its deployments in Iowa and Missouri. In Iowa, the CB system was effective at warning drivers of upcoming road conditions. The system reached a large portion of the targeted audience and passed on information that was important to listeners. In Missouri, the CB messaging system was associated with improved lane distribution, especially for non-passenger vehicles. It was also associated with higher speeds upstream from the lane closure but lower speeds near the lane closure, and improved higher standard deviations of speed upstream from the lane closure but lower standard deviations of speed near the lane closure (MwSWZDI 2000).

Because this technology has had several deployments, DOTs (for example, Pennsylvania) have policies encouraging the use of the CB system. Other deployments of this technology include Interstate 65 near Louisville, Kentucky, Missouri, and Indiana.

THE ROAD AHEAD

The research team will continue to conduct several visits to neighboring states where traffic management technologies have been deployed. An evaluation of these technologies will be performed in an effort to determine the impact on safety during the construction work. It is imperative not only to measure the reduction in number of accidents, but also to document a detailed cost/benefit analysis for the deployment of any of the herein presented systems.

CONCLUSIONS

This paper is intended to give an overview of various traffic management technologies analyzed as part of the research project titled Improving Construction Work Zone Safety.

Maintaining traffic flow and safety of motorists and construction workers in Interstate work zones are major concerns for DOTs. Delays, long queues and lines of halted vehicles are growing irritant for motorists. Accidents tend to increase when there is an increase in construction activity. In order to reduce the frequency of crashes occurring in these work zones, traffic agencies have implemented different technologies to provide road users with more information of the dangers that lie ahead.

The systems, AIMS, TIPS, ASIS, and WIZARD, attempt to influence drivers behavior in an effort to decrease the number of accidents and fatalities near a work zone Although, the benefits of these technologies are obvious, they can be sometimes outweighed by the cost of the traffic management system itself if not deployed appropriately.

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Construction Industry Benchmark of Key Performance Indicators

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ABSTRACT

Construction companies in the UK are now making a significant investment in developing performance measurement as a management technique and strategy. This is an aftermath of the Construction Task Force report 'Rethinking Construction' in which Sir John Egan called for the development of a set of benchmarks for the construction industry. Since then construction Key Performance Indicators (KPIs) have unveiled. In May 1999, the UK Construction Industry Board published the first set of KPIs for the construction industry with seven of the indicators relate to project performance and three are measures of company performance. The UK KPIs Working Group produced a KPI framework consisting of seven main groups (time, cost, quality, client satisfaction, client changes, business performance, and health and safety). The indicators are designed to provide construction firms and their clients with a means to judge or measure performance and to assess or implement improvements in the industry. Based on a list of 25 key performance indicators against which a firm or an industry could be assessed, this paper documents the UK construction contractors assessment of the construction industry performance. The study, which adopted a questionnaire survey approach, examined three main issues: (1) the construction industry perception of world class industries/sectors; (2) construction contractors' assessment of the construction industry against the world class industries; and (3) an evaluation of the construction contractors' performance.

Keywords: Benchmark, Performance indicators, Client satisfaction, World Class Industries

INTRODUCTION

This paper documents empirical evidence from the construction contractors' perspective, the importance level of 'key performance indicators', and whether they consider that the industry should continue to benchmark good performance within or outwith the industry. The attributes and factors on which a certain practice could be benchmarked are numerous. Sometimes, it is either not worthwhile (say, expensive), or impossible to benchmark the activities of an organisation on all the possible attributes or factors. In this circumstance, a few representative attributes or factors, known as *key performance indicators* (KPI) are used. KPIs are critical to the success of an organisation. The use of KPIs for benchmarking must therefore be able to afford a true reflection of the general performance of an organisation that is being assessed, though other attributes/factors might have been ignored deliberately.

KPIs and benchmarking have become important drivers of construction improvement. Sir Michael Latham (1994) advocated a 30% cost reduction in construction project delivery. This target was aimed at being achieved by the year 2000, under a benchmarking system. The Construction Task Force report, 'Rethinking Construction', by Sir John Egan (DETR, 1998), called for the development of benchmarks for the construction industry.

In pursuit of the Egan and Latham agendas, the CIB released a KPI-framework for construction practice in 1999. Ten KPIs are specified in this framework, and they are (www.gottardo.emeraldinsight.com/): actual cost; actual time; predictability of costs; predictability of time; defects; safety; productivity; profitability; client satisfaction with the product; client satisfaction with the construction process. Three of these KPIs (i.e. profitability, productivity and safety) are measures of company performance, while the other seven relate to project performance.

The UK construction industry KPIs are presented as graphs, which denote the industry average, and individual organisations can assess their performance with respect to the national average. In addition, separate KPIs have been produced for sectors such as new public housing; new private housing; new-build non-housing (public); new-build non-housing (private); infrastructure; and repair, maintenance and refurbishment (Martin, 1999).

The foregoing ten KPIs can be detailed out in terms of attributes, and can be assessed at the headline, operational or diagnostic level (DETR, 2000). The headline level provides a quick macro (approximate) assessment of the performance of an organisation. The operational assessment concerns the performance of activities with the aim of identifying specific areas for improvement. The diagnostic level of assessment provides the rationale, why certain changes had occurred at the two previous levels, and describes in detail how they are useful for improvement.

For general assessment of an organisation's performance, five key project stages have been delineated for using these KPIs, for different forms of procurement. These five stages are commitment to invest; commitment to construct; available for use; end of defect liability period; and, end of lifetime of project. In addition to the stage assessment of project performance, the analysis can be extended to the supply chain and its attendant activities. The services of subcontractors, suppliers, advisers (consultants) and clients are expected to be assessed by a contractor (DETR, 2000).

The construction industry has been encouraged to use these KPIs for assessing performance, and for this purpose, the KPI graphs are produced annually by the Construction Best Practice Programme (CBPP) to show the performance of the construction industry on these indicators (DETR, 2000). The CBPP is a product of the CIB, in conjunction with DETR, Construction Clients Forum, and the Movement for Innovation, who will continue to jointly published the KPI wallcharts, to provide firms with a basis for measuring and comparing their performance with the rest of the industry.

Many construction companies are now making extensive use of these KPIs to measure their performance and assess improvements in the industry overall. These KPI models produced for the various activities of the construction industry enable benchmarking to be carried out.

OVERVIEW OF LITERATURE ON BENCHMARKING

Benchmarking was originally used by land surveyors to compare elevations but, nowadays it has assumed a narrower meaning in the context of best practice (Kouzmin *et al.*, 1999). A benchmark is in this regard, the 'best in class' level of performance that can be achieved in the now, and for a specific business process or activity (www.kpizone.com). Benchmarks are thus used as a reference for comparisons in benchmarking.

Benchmarking is the act of identifying the highest standards of excellence for products, services, or processes ('best practices'), and making improvements to attain to those standards (Elmuti and Kathawala, 1997). It concerns the measuring of an organisation's performance against others in key business activities, and then using lessons learnt from the best practices, to make targeted improvements in a particular organisation.

Any organisation that is benchmarking its activities is constantly looking for other organisations world-wide, and regardless of industry, to ascertain better practices. Whenever areas of improvement are discovered, practices are either immediately changed, or goals for directing change are established.

Benchmarking is ideally, not a one-off activity, but a continuous and iterative process that is carried out on a regular basis. For a company to embark on benchmarking is thus, tantamount to a commitment to continuous improvement. It is effectively a culture that is, (or, can be) imbibed.

Benchmarking is said to have originated from Japan, and was pioneered in the West, in the seventies, by the Rank Xerox Corporation (Zairi, 1994). The scope for benchmarking is very broad. While the whole activities of an organisation can be benchmarked, it is also possible to limit a benchmarking exercise to some selected aspects, especially those aspects where high under-performance has been identified.

Benchmarking can also be carried out either to keep pace with, or outwit competitors. In the former, the competitors are used as the best practice models, while in the later, other organisations (and not the competitors) are emulated. The practical advantage of comparing the practices of an organisation with non-competitors is that information can be obtained much quickly. On the other hand, competitors are rather reluctant to share information especially if it is commercially sensitive, and may feel threatened that, the benchmarking of their activities may uncover some unworthy practices (Kouzmin *et al.*, 1999).

Benchmarking enables an organisation to (Zairi, 1994; Elmuti and Kathawala, 1997, Brah *et al.*, 2000) achieve the following:

- Identify its position with respect to the global market;
- Learn new ideas from others;
- Update its goals;
- Increase productivity and/or quality of goods and services;
- Decrease costs of operations;
- Identify potential areas of growth;

- Identify weaknesses which have remained unknown;
- Increase the reliability of its operations;
- Stir up self-believe;
- Partner, or do joint ventures with market leaders;
- Identify emerging technologies and practices that are entering the sphere of business;
- Systemise the formulation of strategy; and,
- Serve its customers more quickly and to better satisfaction.

However, a negative connotation of benchmarking has been raised, which is, that users of benchmarking are merely copying others instead of being innovative. It has been suggested by Zairi (1994), that benchmarking be conducted within the framework of 'Total Quality Management' (TQM). Credence to this suggestion can be found in the European Foundation for Quality Management (EFQM) model for TQM. This model, which was subsequently renamed the 'model for business excellence', sets the scene for organisations to identify their key drivers for continuous improvement and to concentrate on them (Sommerville and Robertson, 2000). To subsume benchmarking within TQM is to emphasise quality as one of the key factors to be improved and sustained.

Process and Problems of Benchmarking in Construction

The benchmarking process involves, first of all, an audit of the current performance of an organisation, sector or market. While carrying out this auditing, the performance of the subject being studied is measured against an established benchmark (KPI). The scope of the KPI criteria is ranged to reflect the aspects which, are being benchmarked.

A Likert type of scale can be used for the scoring of KPIs (Roest, 1997), as well as 'balanced scorecards' (Sommerville and Robertson, 2000) and point-scores (DETR, 2000). Subjective assessment, in terms of low, medium, high, may also be used. Ranking and descriptive score scales have been discussed by Longbottom (2000). Graves *et al.*, (1998) had suggested that, the universally accepted methods of measuring project performance were few.

In benchmarking, a 'best practice' that would be the target of comparison, is identified. Meanwhile, the search for best practice is very difficult and takes a lot of resources (Kouzmin *et al.*, 1999). The best practice that had been identified is next assessed on the same criteria used for the company's own-assessment. A comparison between the two sets of measurements is then made. Deviations between the two, (positive and negative) are expressed as percentages. More significant, is that shortfalls in the performance of the assessor-company are identified, and reasons for such shortfalls are primarily established. Steps to step up the standards of the assessor-company, in order to match those of the firm being benchmarked, are then sought and implemented. Employees need to understand the concept and implementation of benchmarking, and thus new standards established from the exercised have to be explained to them.

Literature groups the foregoing process in four phases (e.g., Longbottom, 2000): planning, analysis, implementation (set goals, communicate) and review and repeat/iterate the previous steps. The benchmarking process is maintained on a continuous basis, and is done for various aspects. In an industry where products or processes change very frequently, the need for frequent iterations of the benchmarking process is ever crucial, as the 'best practice' keeps changing. If a bench-marker is to remain competitive, the frequent review of benchmarking must remain paramount.

Brah *et al.* (2000) identified four dimensions to benchmarking as follows: (1) Internal (where one project is benchmarked with another within the portfolio of an organisation); (2) Competitive (where an organisation benchmarks its products or services using that of a competitor); (3) Functional (based on non-competitors carrying out the same functional activity); and (4) Generic (where an organisation benchmarks its services or products with that of others irrespective of industry or country). This paper by adopting Brah *et al.* (2000) categorisation of benchmarking looks at the generic benchmark.

As a concept, benchmarking is simple, but as a practice, it can be difficult to implement. Empirical and theoretical evidences suggest practical downsides of benchmarking, especially pertaining construction engineering. Notable downsides of benchmarking in construction include those identified by McHugh *et al.* (1995), Roest (1997), Hinton *et al.* (2000) and Sommerville and Robertson (2000) as follows:

- Identification of suitable partners.
- Obtaining comparable data could be quite difficult especially that, construction products tend to be unique at the micro level.
- Resistance to change by staff who would effect new standards.
- Resources for benchmarking (qualified staff, time, etc.) may be limited.

- Eliciting full co-operation from 'best practices' may be futile especially where confidential information is involved.

- Intangibles may not be measured accurately.

- Organisational instability or collapse, due to workload variations can erode the basis of a comparison.

- The creation of new networks (relationships) re-invents the wheel, and fails to build on experiences gained from previous projects.

METHODOLOGY – SURVEY, RESPONDENT CHARACTERISTICS AND DATA ANALYSIS

To obtain information from construction contractors on the key performance indicators and to know where the construction industry stands in comparison with the other 'world class' industries, a postal survey of the top 100 UK contractors was undertaken. The questionnaire design was based on a combination of an extensive review of the literature dealing with key performance indicators and the UK Department of the Environment, Transport and Regions publication on KPI. The final questionnaire was developed with the aid of a pilot study with two major contractors that have developed and implemented KPI for their operations. Thirty three firms returned completed questionnaires in a usable format. The response rate of 33% was considered high compared to the norm of 20 -30 per cent with most postal questionnaire surveys of the UK construction industry. Tables 1 and 2 show the designation and the construction experience of the respondents, respectively. The respondents are all at the senior management level with an average construction experience of about 27 years (standard deviation = 9.7).

Table 1 Designation of the respondents

Position	Overall	Percent
Managing Director / Chief Executive	18	54.5
Directors	11	33.3
Managers	4	12.1
Total	33	100

Directors are Group, Commercial, Finance, Operational, Business Development Managers are QA/Technical, Construction, Corporate Development and Commercial.

Table 2 Years of construction experience

Year	Frequency	Percent
Less than 10 years	2	6.1
10 – 20 years	6	18.2
21 – 30 years	13	39.4
31 – 40 years	9	27.3
Over 40 years	3	9.1
Total	33	100.0

Mean = 26.67 years (std = 9.69); sum = 880 years

For the analysis presented in this paper, the firms involved in the survey have been classified on the basis of their turnover and number of employees to find out if such measures of size groupings have impact on their opinion. Watt (1980) clarified that the size of a company can be measured in terms of number of employees, net assets (capital employed), value added (net output) and turnover. Tables 3 and 4 show the firms' grouping on the basis of their turnover and number of employee respectively.

Table 3 Turnover of Firms

Turnover	Frequency	Percent
Less than £100 million	13	39.4
£100 - £250 million	11	33.3
Over £250 million	9	27.3
Total	33	100.0

Mean = £198.64m, min = £22 million, max = £1000m

Table 4 Number of employees within the firms

	Frequency	Percent
Less than 500 Employees	13	39.4
500 – 1000 Employees	12	36.4
Over 1000 Employees	8	24.2
Total	33	100.0

Two separate statistical analyses were undertaken using the Statistical Package for Social Sciences (SPSS). The first analysis identified the sectors that the construction industry considered world class for benchmarking. The second analysis ranked the key performance indicators attributable to the sectors based on their turnover grouping and sectorial classification. The factors based on mean value of response; ranked and compared the mean for the groups and produced analysis of variance (ANOVA), which tested the null hypothesis that the mean of the dependent variable (individual factor) was equal in all the groups. As part of the analysis, the Cronbach alpha reliability was produced. Cronbach alpha reliability (the scale of coefficient) measures or tests the reliability of the six-point Likert-type scale used for the study (Norusis/SPSS, 1992). The Cronbach's coefficient alpha in this analysis was 0.8861 (p=0.000), indicating that the 6-point Likert scale used for measuring the KPI of the construction industry in relation to world class industry/sector was reliable at 5% significant level.

BENCHMARKING OF CONSTRUCTION INDUSTRY WITH WORLD CLASS INDUSTRY/SECTOR

The Latham (1994) report highlighted how in both manufacturing and service industries there have been increases in efficiency and transformations of companies which a decade or more ago nobody would have believed possible. Specifically, the report identified the significant performance made in the UK in car manufacturing, steel making, grocery retailing, and offshore engineering industries/sectors. Against this background, construction industry firms were provided with a list of nine industries, to identify one, which they consider to be world-class in terms of performance that should be benchmarked. The list, which can be expanded, comprises of healthcare, automobile, manufacturing, aviation, electronics, retailing, services, major construction firms and petrochemical industries. Table 5 shows that three major industries have been considered by firms to be 'world class', that construction should be benchmarked against. These are the aviation industry (42.4%), the electronics industry (24.2%) and the automobile industry (18.2%).

Table 5 World class industry in terms of quality of product and services

	Frequency	Percent
Aviation industry	14	42.4
Electronic industry	8	24.2
Automobile industry	6	18.2
Others	5	15.1
Total	33	100.0

Others comprise of major construction firms (9.1%), retail industry (3.0%) and Pharmaceutical (3%).

It is not surprising that a majority of the respondents has considered the aviation industry to be the 'world class' sector that the construction industry should benchmark in views of its main features. For example, many policy and regulatory aspects of the aviation industry are governed by the outcome of negotiations between several countries. Within the aviation industry increasing free and fair competition is recognised as the most effective way of securing benefits for consumers, and promoting economic efficiency and innovation. In recent times, the industry has seen the development of global alliances, through which airlines achieve economies of scale and provide a more extensive range of services and destinations. As part of the global alliances, services offered are being extended through code-sharing and franchising, with some cross-shareholdings. The industry is associated with increasing growth, driven by general economic growth and reductions in the real price of air travel. In the industry, safety is given priority and safety considerations are at the heart of its policy (Extracted from DETR, 2000).

ANALYSIS AND RANKING OF THE KEY PERFORMANCE INDICATORS

The respondents were provided with a list of 25 key performance indicators The list includes the ten KPI identified by the UK DETR: actual cost; actual time; predictability of costs; predictability of time; defects; safety; productivity; profitability; client satisfaction with the product; client satisfaction with the construction process. Others KPIs included were those being used by a major UK contractor as reported by Sommerville and Robertson (2000). The firms were asked to rate how the construction industry compared with the performance of the chosen world class industry on a Likert scale of 1 to 6.

Table 6 shows the ranking based on the mean value computed for each KPI. The higher the mean value for the KPIs, the more comparably is the construction industry with the world class industries/sectors in terms of achievement for that KPI. The respondents show that the construction industry compares favourably with the world class industries on the KPIs of teamwork and leadership, employee satisfaction and involvement, impact on society/environment, and return on capital employed.

Table 6 KPI based on turnover grouping

	Total	Rank	Less than £100 million	£100 - £250 million	Over £250 million	F	Sig.
Teamwork and leadership	3.903	1	3.615	3.889	4.333	1.479	0.245
Employee satisfaction	3.719	2	3.615	3.700	3.889	0.172	0.843
Employee involvement	3.719	3	3.692	3.900	3.556	0.182	0.834
Impact on Society / Environment	3.594	4	3.308	3.700	3.889	0.549	0.583
Return on capital employed	3.500	5	3.846	2.900	3.667	0.973	0.390
Achievement of time scales	3.438	6	3.385	3.600	3.333	0.183	0.833
Good practices	3.375	7	3.000	3.700	3.556	2.515	0.098
Risk management	3.344	8	3.308	3.100	3.667	0.596	0.557
Strategy and policy	3.258	9	2.923	3.111	3.889	2.112	0.140
Innovation	3.226	10	2.846	3.556	3.444	0.996	0.382
Customer satisfaction	3.194	11	3.154	3.111	3.333	0.136	0.874
Safety	3.156	12	3.077	3.300	3.111	0.203	0.817
Quality of service and work	3.063	13	2.692	3.200	3.444	2.107	0.140
Partnering	3.033	14	2.769	3.125	3.333	1.039	0.368
Training and Development	3.000	15	2.308	3.400	3.556	4.900	0.015
Work won on value criteria	2.968	16	2.846	2.667	3.444	0.973	0.390
Site image (appearance)	2.871	17	2.462	3.444	2.889	2.096	0.142
Standard of communication	2.813	18	2.462	2.800	3.333	2.569	0.094
IT capability	2.742	19	2.462	3.000	2.889	0.745	0.484
Earnings per share	2.600	20	2.615	1.875	3.222	2.769	0.081
Supply chain management	2.516	21	2.308	2.778	2.556	0.742	0.485
Shareholder added value	2.387	22	2.231	2.333	2.667	0.454	0.640
Waste management and efficiency	2.313	23	2.154	2.200	2.667	0.985	0.385
Profitability	2.219	24	2.462	1.500	2.667	3.140	0.058
Zero defects	2.125	25	1.615	2.800	2.111	2.908	0.071

The KPIs where the construction industry is far below the standard achievable by world class industries are zero defects (mean value = 2.125), followed by profitability (mean value = 2.219) waste management and efficiency, shareholder added value, supply chain management earnings per share, IT capacity, standard of communication and site image (overall mean value = 2.871). These KPIs are those associated with profitability and productivity in the construction industry. Zero defects was considered the most problematic KPI in the construction industry.

With the exception of training and development KPI in which the very large sized contractors compared favourable with the world-class industries/sectors that is significant at 5% level, there is no statistically significant difference in the grouping of the other KPIs by the firms. This suggests that construction firms, irrespective of company size, generally have similar opinions regarding the position of the construction industry on the KPIs. When the KPIs were compared at the 5% confidence level, and based on the grouping of number of people employed, as in

Table 1.4, more variables showed a statistically significant difference. These variables are strategy and policy (p=0.028); innovation (p=0.014); training and development (p=0.001); work won on value basis (p=0.025); and return on capital employed (p=0.032).

Table 7 shows the performance of the construction industry when compared with other industries the respondents had considered world class, as shown in Table 1.5. Although the ranking of industries of several attributes differs, the ANOVA result showed that there is no statistically significant difference in the opinion of the firms' grouping of the other KPIs on the basis of what they consider to be world-class industry. With exception of the other industries group, in which three respondents identified major construction firms as world class sector, zero defects was identified as the least KPI by those who chose aviation, electronic and automobile industries as the world-class industries.

Table 7 KPI based on construction contractors' perception of world-class industries

	Aviation industry	Electronics industry	Automotive industry	Others	F	Sig.
Teamwork and leadership	4.000	3.750	4.000	3.750	0.146	0.931
Employee satisfaction	3.857	3.500	3.500	4.000	0.353	0.788
Employee involvement	3.786	3.375	3.500	4.500	0.816	0.496
Impact on Society / Environment	3.786	3.375	3.667	3.250	0.250	0.860
Return on capital employed	3.857	3.500	2.333	4.000	1.362	0.275
Achievement of time scales	3.500	3.250	3.333	3.750	0.238	0.869
Good practices	3.286	3.250	3.500	3.750	0.404	0.751
Risk management	3.286	3.500	3.000	3.750	0.400	0.754
Strategy and policy	3.214	2.875	4.200	3.000	1.561	0.222
Innovation	3.000	2.750	4.000	4.000	1.717	0.187
Customer satisfaction	3.286	3.250	3.200	2.750	0.324	0.808
Safety	3.071	3.000	3.500	3.250	0.458	0.714
Quality of service and work	3.000	3.000	3.333	3.000	0.200	0.896
Partnering	2.786	3.250	3.000	3.667	0.940	0.436
Training and Development	2.857	3.250	3.333	2.500	0.579	0.634
Work won on value criteria	3.214	2.625	3.167	2.333	0.666	0.580
Site image (appearance)	2.571	3.250	3.000	3.000	0.623	0.606
Standard of communication	2.643	2.625	3.167	3.250	0.833	0.487
IT capability	2.571	3.000	2.400	3.250	0.689	0.566
Earnings per share	3.000	2.625	2.000	1.667	1.497	0.239
Supply chain management	2.286	2.625	2.600	3.000	0.743	0.536
Shareholder added value	2.643	2.375	2.167	1.667	0.814	0.498
Waste management and efficiency	2.286	2.500	2.000	2.500	0.398	0.755
Profitability	2.643	2.250	1.667	1.500	1.618	0.208
Zero defects	1.714	2.500	1.833	3.250	2.200	0.110

CONCLUSION

The Latham and Egan reports had reinforced the opinion that the UK construction industry was under performing. The chronic quest for improvement thus led to the establishment of key performance indicators, which can be used to monitor both individual and industry performance. As many organisations have used these indicators to appraise their performance, the research at Glasgow Caledonian University sought, in part, to see how the construction industry was faring in relation with world class industries.

Overall, the analysis of the key performance indicators suggests that the construction industry is comparable with what they have considered 'world class' industry on some KPIs, including teamwork and leadership, employee satisfaction and involvement, impact on society/environment, and return on capital employed. However, the construction industry is under performing in the aspects of zero defects, profitability, waste management and efficiency, shareholder added value, supply chain management, earnings per share, IT capacity, standard of communication and site image. The contractors' responses suggest that the construction industry should benchmark its practices against other industries outside the construction industry, particularly the aviation and electronic industry, rather that the current practice of benchmarking the best practices from within the industry.

In conclusion the construction industry should strive to investigate more, how other industries such as the aviation, electronic and automobile are achieving good performance in the three major areas where it is under-performing, that is: zero defects, profitability, waste management and efficiency. Achieving zero-defect product quality by eliminating the root causes of defects using philosophies such as Total Productive Maintenance (TPM), Total Quality Control (TQC) and Just in Time (JIT) are constantly being reported at world class electronic and automobile manufacturing plants. The construction industry should start investing in benchmarking models that integrate machines (capital), quality and people (MQP) attributes into a management approach that is associated with world class industries.

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A Method to Improve Worker Safety – Pareto Analysis of Construction Accidents

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ABSTRACT

This work describes an application of the Pareto principle to worker safety and suggests that in most cases, accident losses are distributed in a way such that a vital few types of accidents and types of injuries make up the largest portion of overall safety losses either in terms of accidents or lost work hours. Safety improvement plans and resources can then be directed to the correction of the vital few defects, thus maximizing the effective use of available resources. This study uses actual jobsite safety data from highway construction projects to create seven diagrams which examine the relationship between body part injured, types of injuries, severity of injuries, and frequency of occurrence. The Pareto charts are then used to formulate recommendations for worker safety improvement programs on future highway construction projects. Conclusions detail shortcomings and successes of the Pareto Analysis approach, as well as summarize the methodology's worker safety improvement recommendations.

INTRODUCTION

This study concentrates on three years of safety records of accidents recorded in the construction and maintenance divisions of a portion of a state public transportation agency. Data analysed includes 716 separate accident reports from January 1, 1996 to December 31, 1998. Previous research has suggested that accidents are distributed in a way such that a vital few types of accidents and types of injuries make up the largest portion of overall safety losses either in terms of frequency of accidents or lost work hours (Kuprenas et al 1999). This work describes a second application of this Pareto principle to the accident data. This study uses presents six diagrams that examine the relationship between body part injured, types of injuries, severity of injuries (measured through lost work hours), and frequency of occurrence.

Accident records incfulude data related to the individual involved in the accident as well as the injury itself. This study concentrates on three elements of the accident records – type of injury, body area injured, and number of days lost from work. The first element considered in the study was the part of the body injured. Body parts recorded as injured in the study data set include:

- ✓ Abdomen
- ✓ Ankle
- ✓ Arm
- ✓ Back/low
- ✓ Back/Upper
- ✓ Buttock
- ✓ Calf
- ✓ Chest
- ✓ Circulatory
- ✓ Ear/hearing
- ✓ Elbow
- ✓ Eyes/vision
- ✓ Face
- ✓ Finger
- ✓ Foot
- ✓ Forearm
- ✓ Genitals
- ✓ Groin
- ✓ Hand
- ✓ Head
- ✓ Heart
- ✓ Hip
- ✓ Internal organs
- ✓ Knee/low
- ✓ Mouth/teeth
- ✓ Multiple
- ✓ Neck
- ✓ Nervous System
- ✓ Nose
- ✓ Psychological
- ✓ Respiratory
- ✓ Rib
- ✓ Shoulder
- ✓ Spine
- ✓ Thigh
- ✓ Toe
- ✓ Whole body
- ✓ Wrist

The second element analyzed is the type of injury. Injury types are based on the physical mechanism of the injury and vary greatly. Types of injuries within the three-year data set include:

- ✓ Abrasion
- ✓ Amputation
- ✓ Bite/sting
- ✓ Bone fracture
- ✓ Bruise
- ✓ Burn/scald
- ✓ Cancer
- ✓ Concussion
- ✓ Crush/pinch Cum. Trauma
- ✓ Cut/puncture
- ✓ Dermatitis
- ✓ Dislocation
- ✓ Emotional Stress
- ✓ Hearing Loss
- ✓ Hernia
- ✓ Infectious disease
- ✓ Inhalation
- ✓ Irritation
- ✓ Multiple
- ✓ Neurological
- ✓ Overexertion
- ✓ Pneumonia
- ✓ Soreness
- ✓ Splinter
- ✓ Sprain
- ✓ Strain
- ✓ Stroke
- ✓ Torn muscle

The last element of the study is the days lost from work. The number of days lost varied from zero (622 occurrences) to ninety (one occurrence) with an average value (for all 716 accidents included in the study) of 1.5 days. A histogram distribution of the lost days by accident is shown in Figure 1.

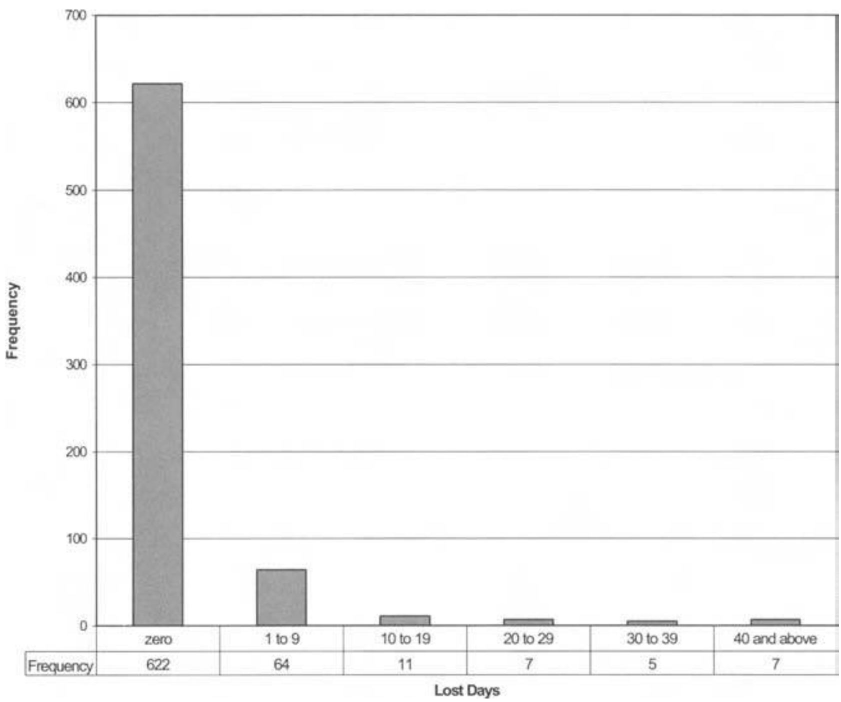

Figure 1. Histogram of lost days

PARETO ANALYSIS

A Pareto analysis was conducted based on the above three elements of the 716 injury records – type of injury, and body part injured, and lost days. The Pareto Principal is based upon the observation of Vilfredo Pareto in nineteenth century Italy that 20% of the population controlled about 80% of the wealth. Researchers have applied Pareto's concept to many other topics other than wealth distribution and have found that in most cases, occurrences are distributed in a way such that a vital few make up the largest portion of the population of outcomes -- but not always strictly in a 20-80 relationship (Juran 1989). The Pareto diagram is a graphic representation of this concept. The Pareto diagram itself is a histogram with the categories of data arranged in order from the largest the smallest and a cumulative curve for all outcomes. Used in research applications, Pareto diagrams graphically allow the separation of the vital few items from which the majority of occurrences are generated from the trivial many. Resources are then directed to the vital few, thus maximizing the effective use of available resources. Used in such a fashion, Pareto diagrams have been used or proposed in a number of applications such as quality control (Kuprenas 1998), engineering management (Graves 1993), and safety (Kuprenas et al 1999).

Analysis by Body Part

The initial analysis of the data from the transit agency focused on which part of the body was most frequently injured and how severe were the injuries. Figure 2 shows a Pareto chart created for frequency of injuries by body part. The chart shows the body part injured on the x-axis and frequency of occurrence and cumulative percentage of occurrence on the two y-axes. Review of the figure shows that the most commonly the body part injured on the x-axis and frequency of occurrence and cumulative percentage of occurrence on the two y-axes. Review of the figure shows that the most commonly injured body part is the lower back, the second most common is the knee, and the third most common is the finger. These three items were identical to the top three body parts identified in a similar study of accidents in construction and maintenance operations at a naval facility (Kuprenas et al 1999). The trivial few (although no safety issue can truly be categorized as trivial) body parts injured (occurring fewer than ten times) ranged from calf to toe as shown below and represented only 10% of the total accidents. In order to keep the figure legible, Figure 1 does not show 8 body parts representing 23 accidents, each of which occurred fewer than five times

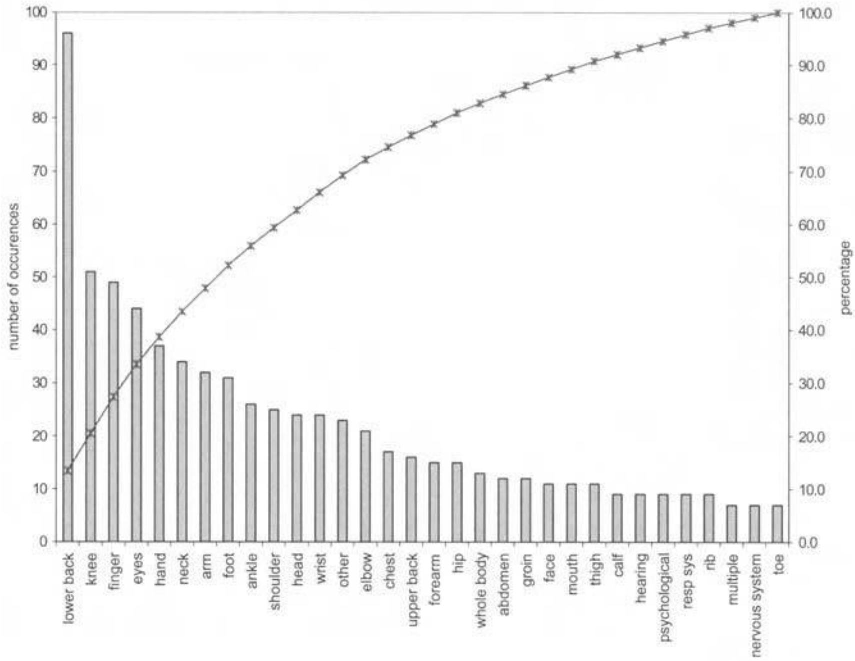

Figure 2. Frequency analysis by body part

over the three years of data in the study. The Pareto principal was somewhat visible for this date. In order to reduce accident occurrences in agency operations, safety management efforts should focus on protection of the back, knees, and fingers.

The research team then considered the amount of time lost due to accidents for each body part. Figure 3 shows a Pareto chart for lost hours by body part injured. The chart again shows the body part injured on the x-axis, but the left y-axis shows the total time lost due to accidents for each body part. The second, right, y-axis shows a percentage of cumulative time lost. Review of the figure shows that the injured body part requiring the most time lost from work is the knee, the second time loss required comes from the lower back, and the third most time loss comes from the heart. Note that the heart was not even identified on the frequency Pareto chart (Figure 2). All 90 of the lost hours from the heart injury came from a single incident/accident. The Pareto principal was somewhat more valid in this case with 38% (10/26) of body parts injured accounting for 80% of the lost work days. Again, in order to reduce lost work hours at the agency, safety management efforts should focus on protection of the back and knees. Heart protection, however, must be addressed through a separate safety analysis, and would likely required modified work processes rather than protective measures.

Analysis by Injury

The second type of analysis of the data from the transportation agency was construction of a Pareto chart for the body part injured. Figure 4 shows a Pareto chart for frequency of injury based on type of injury. The chart shows the type of injury on the x-axis and frequency of occurrence and cumulative percentage of occurrence on the two y-axes. Review of the figure shows that the most common type of injury is strain, the second most common is sprain, and the third most common is cut. The "trivial" few types of injuries (less than ten occurrences) ranged from hernia to infections represent over 75% of all types of injuries (22/29), but account for only 28% of all incidents (298/716). The Pareto principal was well demonstrated by this data.

The research team then considered the amount of time lost due to accidents for each body part. This analysis is shown in Figure 5. The chart shows the type of injury on the x-axis, but the left y-axis shows the total lost days due to each type of injury. The right y-axis shows a percentage of cumulative time lost. One type of injury (strain) accounted for over 20% of the total lost work days. Hence, in order to reduce lost work hours at the transportation agency, safety education and protection efforts should focus on how to avoid strains.

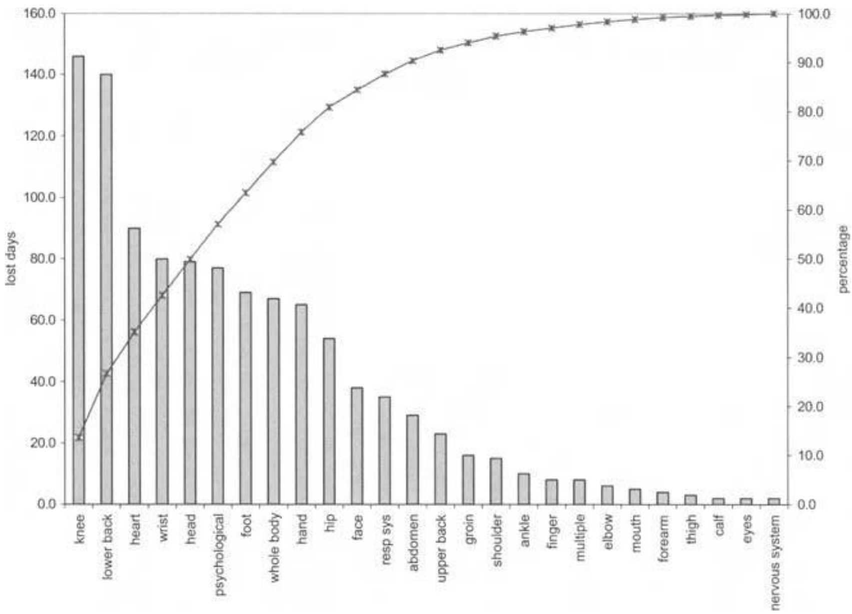

Figure 3. Lost days analysis by body part

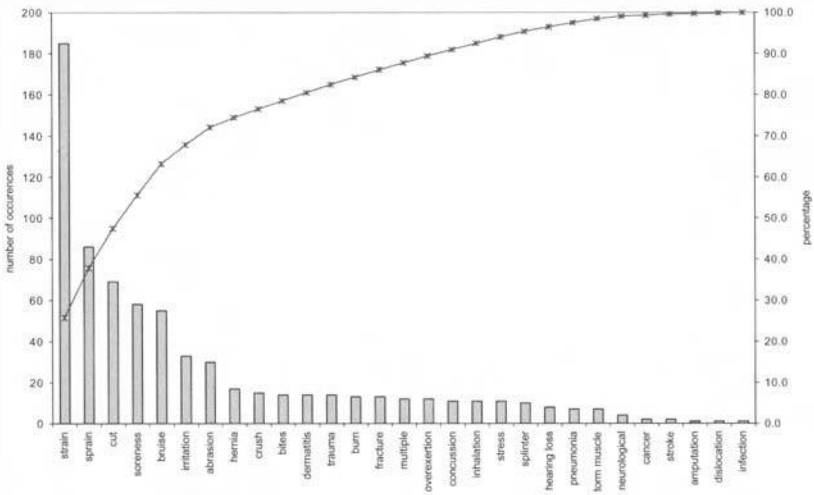

Figure 4. Frequency analysis by injury type

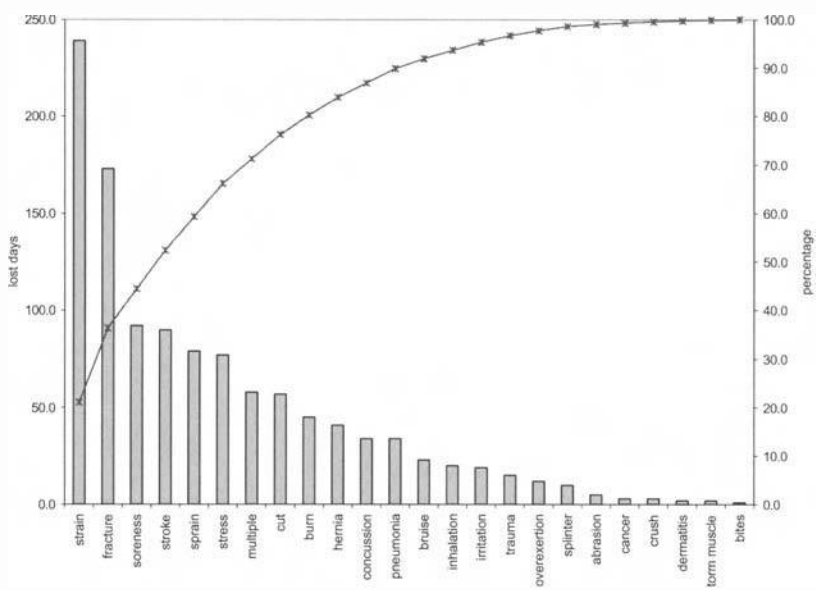

Figure 5. Lost hours analysis by injury type

Pairwise Analysis

Analysis of Figures 2 through 5 showed that the back and knee are the most critical body parts to protect, while strain is the most critical injury to be prevented against. Analysis then questioned whether most common injury combination is strained backs or knees. A pairwise analysis Pareto chart for frequency of injuries (body part to injury type) was conducted to check this hypothesis and is shown in Figure 6.

The Pareto chart shows the body part injured on the x-axis and frequency of occurrence and cumulative percentage of occurrence on the two y-axes. The chart was created for all data pairs which had over five occurrences (34 pairs). A total of 267 pair combinations occurred less than five times and were not shown in the analysis. Review of the figure shows that the most common combination is in fact the back – strain pair representing twice as many occurrences as the second most frequent body part-injury pair. The Pareto principal was somewhat valid in this case. The research team then considered the lost time accidents for the pairwise combinations as shown in Figure 7. The Pareto chart shows the body part injured on the x-axis and lost hours and cumulative percentage of occurrence on the two y-axes. The chart was created for all data pairs that had 20 or more days of lost time (19 out of 301 pairs). Review of the figure shows that the most hours are lost from the bone – fracture, heart – stroke, and foot – soreness pair combinations. The back – strain combination is only the fifth item in the Pareto chart. Again, the Pareto principal was valid in this case; however, the data results were somewhat unexpected in that the most common pair combinations of Figure 6 (frequency) and Figure 7 (lost days) are different. It appears that the most frequent pair combinations do not necessarily result in the most extreme injuries (measured in terms of lost days). In order to improve safety for the agency, management efforts should focus on methods to protect against fractures, as well as training in techniques to prevent strains.

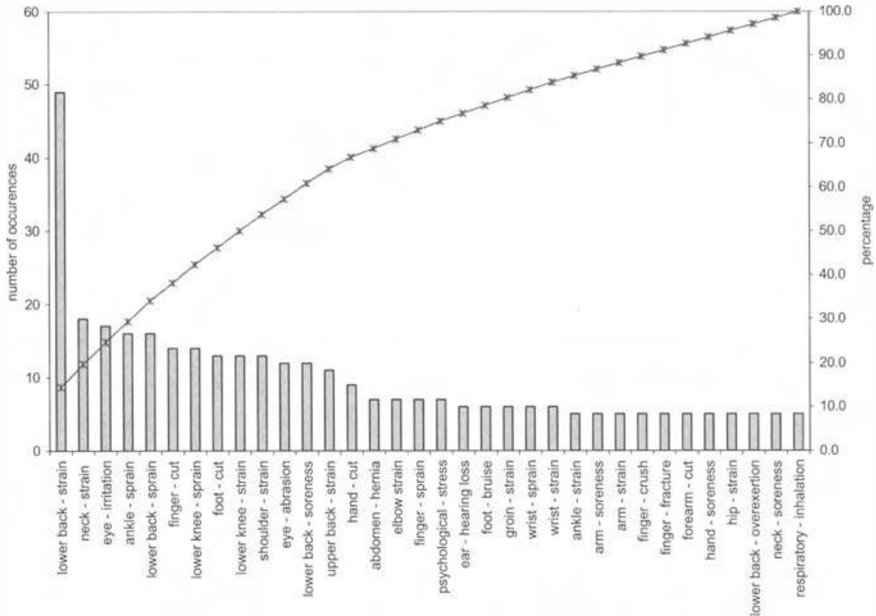

Figure 6. Frequency analysis by pairwise body part - injury type

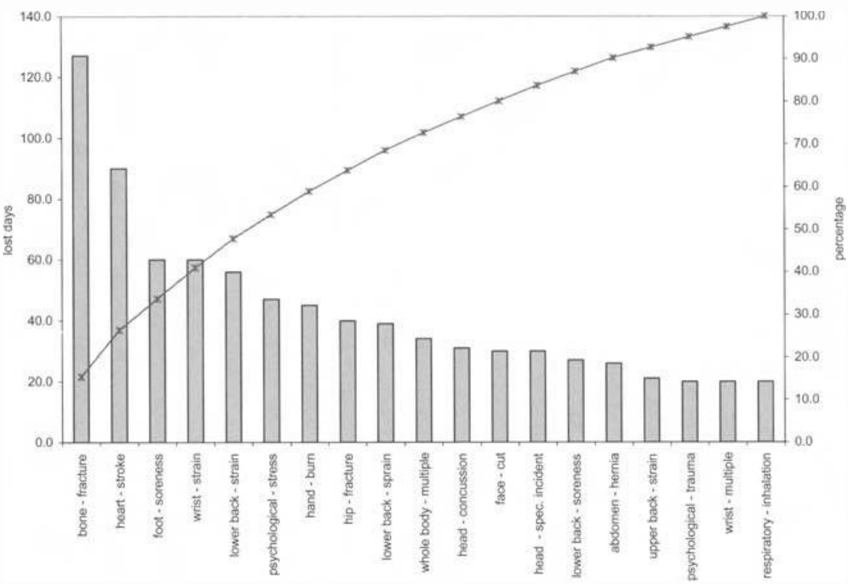

Figure 7. Lost hours analysis by pairwise body part – injury type

SAFETY MANAGEMENT ACTIONS

Similar to the findings of the Pareto study at the naval facility (Kuprenas et al 1999), the researchers recommend an accident chain analysis for transportation agency. The accident chain accident management approach focuses on correcting the events that lead to an accident, rather than the accident itself (Loosemore 1998). The Pareto analysis has shown that strained lower backs is a significant problem. Rather than focusing on the lifting itself (the reason for the accident) and recommending lifting belts and proper lifting procedures in construction practices, the agency should to determine why backs and knees are being strained and then change the circumstances that lead to the practice. For example, perhaps lifting assistance devices are being used as much as they should (hoists, pulleys, or lifts), hence employees are being injured because they are overexerting themselves, regardless of lifting technique. An accident chain analysis, however, is never simple. A study of the problem of knee injuries or heart problems for the agency would likely show hundred of possible events which led to the injury. Other issues beyond the event chain may also be of value to management plans. Additional research is needed in these areas.

CONCLUSIONS

This work has described an application of the Pareto principle to accident data and has shown that, accident frequency and losses are distributed in a way such that a vital few types of accidents and types of injuries make up the largest portion of overall safety losses either in terms of frequency of accidents or lost work hours. This study has examined data from a state transportation agency's construction and maintenance operations and has found strains of backs and knees to be the most common injuries, and bone fractures to be the injury that results in the most time lost work days. A accident chain analysis is recommended to identify events that lead to the accidents. Additional research for additional years of data is needed to develop safety management plans and to further study the validity of the Pareto principle.

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Multiple Safety Cultures at the Construction Site

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INTRODUCTION

Safety at the construction site continues to be an unsolved problem, if we consider the evaluated number of accidents occurring in the sector every year. For example the Danish construction sector has been marked the last year by several lethal accidents related to the handling and assembling of precast concrete elements (Nielsen, 2001). These accidents highlight once again that prevention has to be a broad orchestration of efforts (Kamp & Koch, 1998). Safety measures start within the design phase, but also encompass quality demands to components like the precast concrete elements. Turning to the site, safety prevention is an issue of management, organisation, equipment, training, coordination and communication as well as personal protection equipment.

Within this totality however there is a room for looking at safety cultures. Shared meanings on risk-taking, perceptions on the means of or even possibility of prevention, shared symbols and metaphors are central in this perspective.

The paper reports on Danish site experiences with safety cultures understood as part of the organisational culture. Multiplicity and ambiguity are central characteristics. The site investigated inhibited one relatively weak common culture, which coexisted with a number of other cultures, which cover parts of the site only. Some of these are following patterns of crafts others employment relations. At least two safety cultures are a "layer" in this multiple configuration of cultures. One culture is characterised by conscious or routinised risk-taking in contrast to another much more cautious safety oriented, which rely yp a higher degree on safety rules. In this way the safety cultures often are in a dualistic relation to each other, (what Alvesson call split dualisms, Alvesson 1993). The paper analyse safety in Danish construction and point at the need for the orchestrated effort, where developing safe cultures in only one tool out of many. Such an effort has become more feasible due to capital concentration among contractors and civil engineers.

METHOD

Safety in construction is understood here as constituted and developed by a number of structural factors as well as actions of actors. A full analysis of these factors is not carried out, but a grid of central features is sketched, drawing on other types of sectoral analysis such as futures for crafts, economic results and expectations etc.

The analysis of safety cultures is developed on the basic of an ethic ethnographic (Martin, 2001) study of organisational cultures at a building site (Christensen 2001, se also Koch 2001, this conference). The time available for the organisational culture study was limited and safety was only an aspect of this. The results are therefore clearly explorative. Three teams of crafts and the site management team were followed with participant observation (Emerson et al, 2001). The craft teams were the masons, concrete element –team and the carpenters. These teams were chosen because they were active in the period where the observer visiting the site. The observer followed the site for two months in the spring of 2001. Each craft team was observed in one workweek (five days). The management team was observed for three days. A number of key actors on the site were interviewed through the two months period (Heyl, 2001). Finally the observer participated in site coordination meetings and health and safety committee meetings. The study of the site organisation encompassed organisational structures, history, occupations, management tasks, skills and health and safety dimensions (Clegg et al, 1996, Koch & Richter 1991). Accidents reported on the site were however not investigated. The author visited the site once and observed the three craft-teams and participated in a coordination meeting. The (symbolistic) ethnographic approach which is adopted here is characterised by an open set of concepts used by the ethnographer in the fieldwork (Geertz, 1973). The ethnographer looks for three types of symbols; verbal, physical and acts. The verbal symbols encompass metaphors, myths and narratives, as well as meaning and interpretations, regarding shared meaning. The physical symbols can be equipment, materials, pictures and the like. Finally also observed actions expressed in a ritual form during daily work are important.

CONCEPTUALISATION OF SAFETY CULTURE

Safety culture is here understood as a specific aspect of the organisational culture(s) (drawing on Koch &Richter, forthcoming). Safety culture is defined as the shared and learned meanings, experiences and interpretations, expressed partially symbolic, which guide actions with impact on risks, accidents and prevention. Safety culture(s) is in interaction with social structures within and outside the organisation and with the organisational culture. Organisational culture studies have been dominated by two main paradigms: functionalism (Schein 1987 a.o.) and interpretivism (including symbolism, Geertz 1993 a.o.) (see also Parker

2000, Alvesson 2001, Schultz 1990, Martin 2001 for reviews). The approach adopted below represents a modified version of symbolism. Culture is here perceived as a perspective on organisation. Focus is on symbols, which can be expressed verbally, physically and by actions. The definitions and analysis of safety culture, is clearly selective, designed in a way that is "practical" and slightly unique in comparison with other studies. The concepts are appropriated to the object of study, which is a Danish building site. We thereby adopt a position similar to culture studies have to be carried out in a specific context (Alvesson, 2001, Guldenmund, 2000). Such studies do not and cannot operate with an entirely stable set of concepts, independent of setting.). In the development of organisational culture theory, as in safety culture, there continues to be controversies on the way to conceptualise and analyse culture (Martin& Frost, 1996). Martins three perspective analysis (differentiation, integration and ambiguity) is used here, as well as the concept of multiple configuration (Alvesson, 1993). This allows the scholar to handle quite complex cultural patterns.

CHARACTERISTICS OF DANISH CONSTRUCTION

The Danish construction sector encompasses a set of players, which is pretty parallel to those of many other northern European countries. The components industry, which is part of the manufacturing sector, is the first link in the supply chain. In the design process, three major civil engineering consultancy companies are carrying out roughly 50% of the building design (FRI, 2001), whereas the contractor side is dominated by three major companies. Even within crafts such as electrical installations, a few companies dominates the market, whereas other like bricklaying still is dominated by small firms (Clausen & Bang, 2001). These capital concentrations are fairly recent, especially among contractors. Two out of the three are by now part of Swedish multinational contractors. The Danish state has traditional been a strong player and more than 95% of the employees are organised in a union, which even in a Danish context is exceptionally high (the Danish unionisation average was 89% in 1994, Scheuer, 1996). The state has played a less active role over the last ten years though.

The public statistics of employment only cover the sub sectors directly involved in construction activities at sites. In these part of the building sector employment have raised from 148.000 in 1992 to 167.000 in 2000 (Danmarks Statistik, 2001). This figure includes administrative and technical staff. According to a trade association, FRI, the civil engineering consultancy sector employs some 15.000 (FRI 2001), a figure which has increased roughly since 1993. Architects are around 20.000 (Abildgren et al, 1996). These increases in employment occurs in spite of a slight decline in production volume for the sector (Økonomiministeriet, 2001).

Several large-scale infrastructure projects such as the Great Belt fixed Link, the Øresund Link and the Minimetro in Copenhagen is either finished or close to be so. Moreover there has been a decline in the building of houses from 1998 to 2000 at (Danske Entreprenører, 2001). On the other hand industrial buildings and farming experienced significant growth from 1996-99. Industrial building is still a growth area.

Future important projects include major investments in telecommunication, which create employment for predominantly electricians, (estimated 1.700 from 2000 to 2001, Danske Entreprenører, 2001), future investments in renovation of the sewerage systems and motorways.

STRUCTURAL FRAMES FOR SAFETY IN DANISH CONSTRUCTION

Danish health and safety reporting and investigations generally do not distinguish between sub-sectors according to risk-patterns when they characterise health and safety in the sector. If any differentiation is done it is done according to trades, which implies that it bundles very different risk patterns. The health and safety status of the sector according to Arbejdstilsynet (1995) and Borg & Burr (1997) is that accidents, noise and ergonomics related to working at knees and carrying heavy load are the three most important work environment problems. The statistics of reported accidents cover roughly 50 % of the actually occurring accidents (Arbejdstilsynet 1996). The statistic for 2000 of NACE group 45 has the following status divided in four groups:

Subsector	No. Of employees	Reported accidents	Accident ratio per 10.000 employees
Earthwork, concrete	51858	1685	325
Masonry, carpenters	48228	1255	260
Finishing operations	18676	234	125
Isolation and installation	48841	1185	243

A previous report (Arbejdstilsynet, 1995) analysed reasons and context where the accidents occurred. The reported accidents exhibit a broad spectre of reasons. Out of ten categories, the three largest are accidents by falling or stumbling (27%), in relation to handling of tools (13%) and to non-intentional act (10%). Statistics on fatalities are more single factorial since falling and stumbling constitutes 36% of the fatalities. Although these figures reveal some basic information on accidents occurring, the figures reveal little about the actual context. Not even further and detailed analysis bring this analysis much further, see for example Kines (forthcoming) on fall accidents in Danish construction.

The construction sector consist roughly of the following sub-areas of product types, which in principle constitutes different types of risk and work environment:

- Private house building
- Public house building
- Business Facility building
- Civil Engineering projects
- Repair and maintenance

Unfortunately the official statistics does not follow these risk patterns. However by combining several sources one can get an interpretation of accident patterns. Although the contractors are active in the first four sub-sectors, it is large-scale civil engineering firms and their handling which have caused the level to be as high as indicated. The level is however lower than previously. As mentioned the contractors are dominated by three major companies which all have issued safety campaigns the later years (Vedsmand, 2001). There is thus a tendency to professionalisation of the safety and accident prevention using a orchestrated set of methods (Kamp & Koch, 1998 discuss the Øresund link). In contrast masonry and carpenters have a predominantly occupation within the first three and the last sub-sector. Both trades are marked by small companies (for masonry see Clausen& Bang 2001), which however presumably are divided into professionalised small firms acting as subcontractors for the big contractors and small scale building companies working predominantly on private housing. This professonalisation might include handling of safety. The plumbers operate roughly 50% in repair and maintenance and 50% on the first three sub-sectors and encompass a combination of large scale and small firms (Dansk VVS, 2001). Summarising, the patterns are broad-spectre and the prevention efforts should cover this spectre, which implicate a broad set of activities (Kamp& Koch, 1998). Especially over the last years it has became clear that a few major players will act systematically in term of proactive (but also reactive) prevention measures. Thank to his trend an arena for discussing safety cultures can be opened. On one hand, a focus on assignment of meaning to acts (behaviour) would be dangerous in a context where substantial proactive safety measures are lacking. On the other hand an entire safety effort built on proactive means would not help companies, which aim at getting further in prevention.

CULTURES AND SAFETY CULTURES AT A SITE

The case is a private housing building project, carried by one of the three large contractors. It is an apartment building in the Copenhagen area. The building contains 178 apartments, the budget is 18,5 million £. The organisation is composed of 52 contracts held by 28 different contractors. Below the focus is on three crafts teams and the site management (the following is drawing on Koch, 2001 and Christensen, 2001).

The precast concrete team

The precast team has 14 members and a foreman, all employed by the main contractor of the site. The team consists of three groups in terms of age: One group of five have worked together for 15 years and are between 55 and 60 years, another group is middle ages and there are four workers of ages between 24-26 years. There is one woman in the team. The division of labour within the team is relatively well defined. There is one team leader, one crane driver, one ground assistant to the crane driver, two element assemblers, an apprentice and eight others which carry out a series of tasks like mounting safety barriers, clearing, moving supporting bars. The element assemblers are responsible for preparing, receiving and mounting the precast elements.

The team is mute during work. Its cooperation occurs with few verbal elements, one gets the impression that the routines are strongly embedded. They know what the others will do and what their own acts are. Verbal metaphors and myths are articulated mainly during the breaks. Narratives on major previous jobs many years back are an example of this. The foreman plays a role as model for the team. The tempo of the group is set by the crane cycles and is moderate.

There are a number of examples of routines risk taking during the work cycles. The element assemblers frequently stand underneath elements hanging in the wires of the crane, the worker responsible for carrying the supporting bars from one floor to the next pass a staircase which is partly occupied with leftovers such as pieces of wood and concrete. Moreover he passes closely by his colleagues with the supporting bar on the shoulder. While the work progresses, the workers need to shift positions on the deck, which sometimes implies climbing or balancing on walls. That the workers are conscious of that this risk taking is counter to safety and also regulations, is illustrated by the following episode:

> While mounting deck elements a young worker has to reposition himself to receive an element at the other side of a wall. Rather than climbing down in a safe way, he chooses to balance on the top of the wall five meter to reach a ladder, which enable him to climb down in the vicinity of the receival of the element. His

> colleague comments: " watch out the white car is there", the young worker smiles as answer. (The Danish Labour Inspection is believed to use white cars).

The safety representative of the team has initiated that a moveable stable ladder and a rolling container for fluid concrete has been invested in. The moveable stable ladder is supposed to diminish the balancing on walls. The safety representative is also responsible for mounting the safety barriers.

The mason's team

The team has 11 members and a foreman, all employed by a sub contractor. The members have ages from 30 to 60. Eight are skilled masons whereas three are unskilled masonry workers. This also constitutes the division of labour between bricklaying and supporting the materials: bricks and mortar. The team is, in contrast to the precast concrete team, loudly shouting during work. The piece-rate induced tempo is high and kept so by a strong work companionship. The team has a marked hierarchy between skilled and unskilled masons. A myth on a skilled mason ordering an unskilled to unduly "over" pack a container underlines the importance of the hierarchy. The work is monotonous and repetitive, but the tempo is held high in common understanding of the importance of high pay (the wage worker perspective). The risk taking is related to the teams' position at a scaffold on the side of the building. Some team members do not wear safety helmets. As long as there is no work done on top of them the risk of falling items is negligible, it is on the other hand not clear, when exactly that is. The tempo of work is actually high enough to produce sweat around the sides of the helmet, which is another reason for taking it of. The site employs a general obligatory helmet rule. However the following episode occurred when visiting the team, illustrating the linking in the meaning system between professionalism and safety precautions:

> When the author arrived at the scaffold with Svend Christensen for the first time, the mason looked (up and down) at the intruding foreigners. The author was wearing rubber boots. One of the masons stepped on the one of the feet to check the boots, while he was looking at his colleague and without saying a word. The boots were safety boots and thus had a hard front. Then they started talking...

This little ritual can be understood as a manifestation of territory as well as implies assignment of meaning to safety protective equipment. The marking of territory could however have been done in many other ways, so it is likely that this manifestations was chosen because rubber boots look soft and thus link to unprofessional behaviour. Since the team emphasises the collective handling of the piece rates, participation in the site safety organisation is not prioritised.

The roof carpenters team

The team consists of five members and a foreman all employed at the same subcontractor. Most of the team members are closely related; three are relatives and one more has been apprentice with one of them. They all belong to the region where the carpenters firm originates (which in this case is remote). The work tasks of the team are diverse: assembly and mounting of roof pavilions and other roof elements. Assembly and mounting of roofs for lift shafts, and ventilation exhaustion and mounting of inner separation walls. The risk taking is related to being on the roof, working with the heavy elements with the lift crane and using hand tools and using a circular saw. The team employs a strong focus on cooperation and professionally developing productive and effective work routines and solutions. Safety is secondary to production. The enthusiasm includes running up the stairs during work.

The site management team

The team or group consists of the project manager, three managers of contractors, an accounting manager, a quality manager, a trainee and a secretary. Four of the managers have cooperated on several projects over the last three years. The rest never cooperated before. The team resides in a barrack central at the site, next to the containers used by the craft teams for break and lockers. For the site management team the focus is on making profit for the company. This motive guides many acts and is also mobilised in interpreting acts of other groups on the site. "Being busy" is important and underlined by symbolic acts such as throwing the phone back in its holder. As one manager puts it

"We need to get the train running"

In relation to safety and risk taking the role of the site management is that of frame setter. The safety plan, the safety committee meeting and the safety issue handled throughout the management activities flag the importance given to safety and the contextual balance between production and safety. Adding to this is the more symbolic acts of wearing safety helmets and shoes whenever entering the site. The site manager acts and tackles the safety committee meeting precisely as the coordination meetings on production issues. The meeting was controlled in an almost military manner sticking closely to an agenda and minutes from the last meeting. Although safety helmets and shoes was used on the site by the management team, some was also operating on the roof without the obligatory safety lines at least at one occasion. The site management thus set an ambiguous frame for safety.

DISCUSSION: THE MULTIPLE CONFIGURATIONS OF SAFETY CULTURES

The analysis of organisational cultures showed a pattern of at least four cultures presumably firm or professional cultures, which are markedly different (the crafts and site management, Christensen, 2001). These organisational cultures are characterised by internal shared meanings especially expressed in common myths and physical symbols but also symbolic acts. It is possible that these cultures are crafts-cultures, which cut across sites, or that they represent local firm-cultures which also prevail across sites. The present study cannot distinguish between great cultures and local cultures, since it focuses on a single site. The work organisation and the task structure imply geographic and social distance between the four. Despite their sharing a common overall task and physical space. There were much weaker elements of a crosscutting common integrative culture. Finally there are ambiguity even within the local cultures, along gender and generation issues.

There are a number of indications that the assignment of meaning to safety, safety rules and prevention measures constitutes *at least two different safety cultures* at the site. One safety culture is marked by conscious risk taking. Safety rules, regulations and authorities are only respected if necessary. This is manifested in the precast concrete team by balancing on walls and standing under elements and it is manifested in the masonry by not wearing safety helmets. Another safety culture is characterised by much more precarious risk-taking and uses of the protective equipment and even active work for improved safety. This includes among others the safety rep. with the precast concrete element team, and the mason workers using helmets and checking the foreigners' boots. Finally the site management team sets a productive imperative as overall meaning system to acts at the site and does not explicitly promote safety.

There are thus multiple cultures, which is overlaying each other across the teams. At the same time there are individuals and ambiguity in meaning systems, which makes a multiple configuration. The production of this cultural pattern is a complex mixture of professional background, experience and ethos, firm policies and practices, similar concerning site management, individual orientations and national frame setting by health &safety authorities and legislation. It is not unlikely that the Danish construction sector and /or the region of Denmark constitute one or several general "great" safety cultures. This perspective is however beyond the present inquiry. Spangenberg et al (forthcoming) discuss and compare reported lost time injuries at the joint Swedish, Danish construction project, the Øresund link. They find less reports among Swedish construction workers, than Danish and explain this by a number of structural factors such as different waging practice during sick leave, different wage and employment systems (regular versus temporary, hourly based versus piece rate) and formalised training versus on the job training. They thus indirectly take the position that the differences between the countries can be at many other features that safety cultures. It can be added that there are activities on safety cultures as means for prevention, but as Spangenbergs et al results indicate many other approaches are relevant on a national level. This is line with Kartam et al (2000), which outline a orchestrated effort for construction safety in Kuwait, which encompass a number of improvements such as better safety organisation. Safety cultures are however not directly addressed, but substituted with efforts (rules) targeting "individual labour behaviour". Kartam points at disorganised labour, extensive use of foreign labour and extensive use of subcontractors as characteristic for the Kuwait construction sector. These characteristics might be explanandums for the lack of safety culture as perspective.

CONCLUSION

This paper commenced by arguing that among a palette of safety prevention methods and measures there might be a precariously chosen role for a safety culture approach. Such an effort has become more feasible due to capital concentration among contractors and civil engineers operating in Denmark. The paper explored the safety culture aspect by focussing on safety cultures as part of a multiple configuration of cultures at a building site in a private housing building project, carried by one of the three large contractors.

The results of the safety culture analysis, albeit explorative in nature, point at a necessary coexistence of multiple safety cultures, rather than one common culture. Moreover it points at the limited role site management play as well as how site management in this case enhanced ambiguity on safety rules. One should not overdo the role of site management, but including their role in a safety culture analysis is important to avoid an overly employee focus. Organisational as well as safety cultures usually cut across functions and hierarchy. The means for integrating cultures are not strong enough in an average construction job. The temporary character contrasts the long-term relationships internal in the teams. The prevention approach should be to understand and allow the different safety cultures and the change these in a more preventive way through training (Lingard, 2001), Labour Inspection campaigns, basic education and other means.

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Review of Fall Accidents in Construction

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INTRODUCTION AND LITERATURE REVIEW

Of the construction workers that suffer fatal injuries, more are involved in falls than any other single cause. This has been a consistent statistic for many years. In a study of construction worker fatalities occurring between 1985 to 1989, it was determined that falls accounted for 33% (Department of Labor, 1990; Hinze, 1997).

Other researchers have examined the prevention of falls by various methods. Singh (2000) investigated fall accidents occurring on low-rise roofs and evaluated some innovative fall protection measures. He determined that there was no single method of fall prevention that would prevent all falls on low-rise roofs; however, prefabrication was determined to be the most promising method, followed closely by the personal fall arrest system (PFAS) and its variants. Duncan and Bennett (1991) reviewed the performance of various fall protection systems, and concluded that both active measures (those that prevent workers from falling, e.g., guardrails) and passive measures (those that protect workers after falling, e.g., safety belts) are useful in reducing fall injuries. Vargas et al. (1996a, b) developed an expert system for construction falls, which analyzed the causes of falls by using fault-tree methods. They concluded that guardrails, safety nets, and PFAS can all be inadequate, under differing circumstances.

Weisgerber et al. (1999) examined the "safety through design" approach which has strong practical implications for construction. They provided an outline of a comprehensive program to prevent falls at the design phase. Gambatese and Hinze (1996), developed a software program to assist designers in addressing safety in design. The software offered many design suggestions, with nearly a third devoted to fall prevention.

Fall prevention was also addressed by OSHA (1998) which has suggested several methods to control fall hazards. These methods include the elimination or substitution of the operation which can lead to falls, the use of engineering controls to guard against falls, informing/reminding workers-at-risk to avoid fall hazards (through warnings and administrative controls such as training and inspections), and the appropriate use of personal protective equipment (PPE).

OSHA has addressed fall prevention in its regulations in recent years. The OSHA revisions to the regulations of particular interest are the following:

1. 1915.159 Personal fall arrest systems (PFAS). The 1996 revised regulations stipulated that it is no longer acceptable to use body belts as a personal fall arrest system. Body harnesses were mandated for PFAS to provide proper protection to workers to prevent falls.

2. 1915.160 Specifications on positioning device systems. This revision, which became effective on January 1, 1998, stated that a positioning device system was not to be used for fall prevention. As a result of this change, only properly tied-off body harnesses are regarded as qualified personal fall arrest systems.

These changes to the OSHA regulations were intended to drastically impact the incidence of fall accidents. Similar conclusions were reached by NIOSH safety researchers in which they found several opportunities for employers and employees to be more vigilant in fall prevention. NIOSH concluded that *"it is essential for employers to develop and implement comprehensive, written fall protection programs where workers are exposed to fall hazards."* (NIOSH 2000).

RESEARCH METHODOLOGY

The purpose of this research was to examine the causes of construction fall accidents and to identify any trends related to fall accidents. A better understanding of the causes of accidents can provide insight into accident prevention. Since falls have been the focus of recent OSHA changes in the regulations, it was also of interest to determine if these modifications might have impacted fall injuries in the construction industry.

The database used in this study is one maintained by OSHA. The initial intent was to utilize the data that are already available on the Internet on the OSHA homepage. While some of the data were contained in this database, the database had not been fully updated since 1996. Since the more recent data were of particular interest in this study, OSHA was contacted and informed of our research needs. The researchers were informed that the updating of the data in the website would not occur in the immediate future. A special request was made to obtain the files directly from OSHA and this was granted. The data were provided in Microsoft ACCESS format and were easily converted to files that could be input into the Statistical Package for the Social Sciences (SPSS).

The data provided by OSHA included all reported OSHA investigations of fatalities and serious injuries from January 1990 through October 2001. The analysis of the data examined all falls in the construction industry in that time period. Subsequent analysis was focused on the most recent years, the period in which the new fall standards were implemented and the period when additional information was being included in the injury records.

RESEARCH FINDINGS

Description of Fall Accidents

The data for the time period from January 1990 through October 2001 included a total of 7,543 OSHA-investigated accidents. Falls (both from elevation and from the same level) accounted for 34.6% of the injuries (See Figures 1.1 and 1.2). It is obvious that the proportion of falls has increased with time in the past 12 years. The average proportion of falls was 34.1% during the years before 1996, and it increased to 38.4%

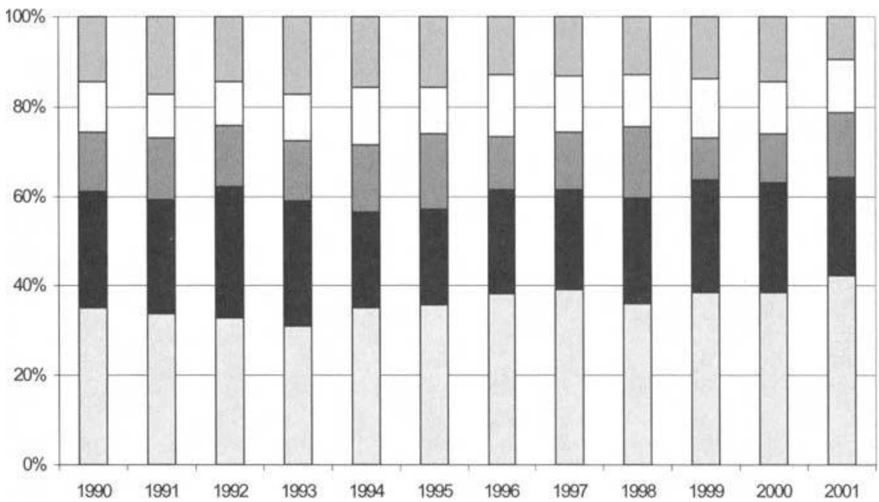

Fig. 1.1 Breakdown of OSHA investigated accidents in construction (01/90-10/01

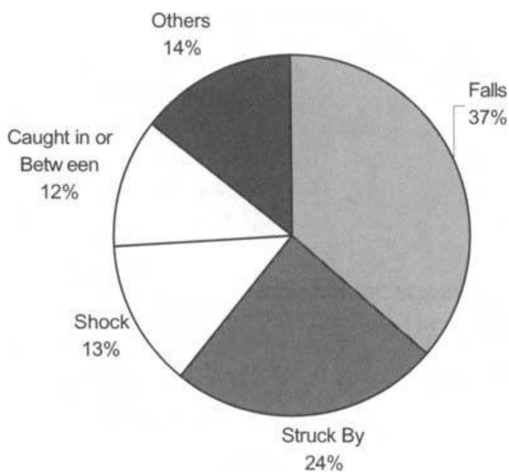

Fig. 1.2 Causes of construction fall accidents investigated by OSHA (01/90-10/01)

in the following years. The total number of OSHA investigated construction accidents is relatively constant during the years. A simple analysis reveals that the Pearson's correlation between the proportion of the falls and the year is 0.841, which provides strong evidence that the proportion of fall accidents increases during the past 12 years.

In the analysis of the other main types of accidents, the Pearson's correlations between the years and the proportions of accidents are: -0.492 for struck-by, -0.232 for shock, 0.469 for caught-in-and-between, and -0.672 for the other accidents. The data may suggest that the proportion of caught-in-and-between accidents has also increased during the years, while proportions of struck-by and shock accidents have decreased. For some unknown reason, the proportion of "other" accidents has decreased.

Among the 7,543 construction accidents investigated by OSHA between January 1990 to October 2001, 2,741 were falls, with 2,687 falls being from elevation and 54 were from the same level. These resulted in 2,955 OSHA recordable fall injuries, with some accidents involving multiple workers. In the analysis, records were found that lacked some information. For this reason, the total number of cases analyzed for different descriptors may vary.

The time of occurrence of falls

The occurrence of falls was examined in regard to the distribution of the timing of their occurrence. July is the month when the occurrence of accidents reaches a peak, while February is the month with the least accidents. This pattern probably reflects the heightened amount of construction activity occurring in the summer and the reduced level of activity in the winter. The distribution of fall accidents seems to be consistent with the occurrence distribution of other accidents as well.

The distribution of fall accident occurrence was also examined in terms of the day of the week. This did not show a clear trend of occurrence, with an even distribution during the workweek, and an expected drop in injuries over the weekend. The analysis also considered fall occurrence in terms of the hour of the workday. The distribution of falls by hour of the day is similar to the pattern observed for other construction accidents. The least number of accidents occur during the lunch hour between noon and 13:00 o'clock and most accidents occur between 10:00 and 11:00 in the morning and between 13:00 and 14:00 o'clock in the afternoon. This is also similar to the distribution of accidents as noted in other research studies (Hinze, 1997).

Types of construction projects and falls

More detailed information was available from the OSHA investigations that took place between January 1997 and October 2001. While some earlier reports may have contained the information about the types of projects, this was not done either consistently or systematically. This results in the more recent years of data providing a richer resource about the information related to falls.

While the information about the types of projects does not implicitly describe the root causes of falls, the information may indicate areas where the focus on fall protection is perhaps most needed. This project information was examined. Findings show that fall accidents occurred more frequently on certain types of projects. Table 1.1 summarizes this information and shows that nearly half of the fall accidents occur on projects involving commercial buildings and single family or duplex dwellings. Whether commercial buildings are multistory or single story, the potential of falls remains a potential hazard. While exceptions exist, many single residential buildings are constructed by small contractors, these firms are known to generally provide relatively informal safety training and inadequate PPE (Glenn, 2000).

Table 1.1 Distribution of injuries by type of facility being constructed

Type of Facility	Falls		All Injuries	
	Count	Percent	Count	Percent
Commercial buildings	404	33.4%	715	22.9%
Other buildings	212	17.5%	412	13.2%
Single family or duplex	211	17.4%	503	16.1%
Multi-family	113	9.3%	183	5.9%
Manufacturing plant	79	6.5%	168	5.4%
Tower, tank, storage elevator	71	5.9%	103	3.3%
Bridge	28	2.3%	94	3.0%
Other	92	7.6%	941	30.2%
Subtotal	**1210**	**100.0%**	**3119**	**100.0%**
Not Known	5		23	
Total	**1215**		**3142**	

Project costs were also examined in this study. The projects with the lower construction costs accounted for the largest number of falls, with nearly one half of the falls occurring on projects costing less than $250,000 (see Table 1.2). This might be expected as the number of smaller projects comprises the larger volume of the construction industry's effort. The type of construction work performed was also examined. This showed that nearly 60% of the falls occurred on projects involving new construction, namely new projects or additions (see Table 1.3). This may also be an expected result as most construction work tends to be new construction.

Table 1.2 Distribution of injuries by cost of project

Project Cost	Falls		All Injuries	
	Count	Percent	Count	Percent
Under $50,000	341	28.2%	990	31.7%
$50,000 to $250,000	229	18.9%	601	19.3%
$250,000 to $500,000	119	9.8%	289	9.3%
$500,000 to $1 million	134	11.1%	341	10.9%
$1 million to $5 million	188	15.5%	464	14.9%
$5 million to $20 million	117	9.7%	244	7.8%
$20 million and over	83	6.9%	191	6.1%
Subtotal	**1211**	**100.0%**	**3120**	**100.0%**
Not Known	**4**		**22**	
Total	**1215**		**3142**	

Table 1.3 Distribution of injuries by type of construction work

Project Cost	Falls		All Injuries	
	Count	Percent	Count	Percent
New project or new addition	721	59.5%	1640	52.6%
Alteration or rehabilitation	219	18.1%	565	18.1%
Maintenance	189	15.6%	531	17.0%
Demolition	41	3.4%	101	3.2%
Other	41	3.4%	283	9.1%
Subtotal	**1211**	**100.0%**	**3120**	**100.0%**
Not Known	**4**		**22**	
Total	**1215**		**3142**	

Fall height

A total of 2,741 fall accidents were examined and of these, 1,018 provided information on the height of the projects and the number of stories. On projects where falls were involved, 807 projects (81%) were either one, two or three stories. The average facility height (whether a building or other type of structure) was 37.4 feet. From this it can be concluded that most falls happened on projects that were not particularly high. Perhaps fall prevention is viewed as a less serious concern on these lower elevation projects.

The data recorded since January 1997 also provided additional information of interest that was not available for accidents occurring in earlier years. In particular, the elevation from which the falls originated and the fall distances of the workers has been consistently documented since January 1997. Of the 1,215 falls that occurred since January 1997, more than 70% occurred at elevations of less than 70 feet. The distribution of the fall heights is shown in Figure 1.3. The average elevations of the fall height (the elevation where the fall originated) and fall distance are 35.4 and 34.9 feet, respectively. Findings show that more than 70% of the fall accidents occur at elevations below 30 feet. The elevation of a project can be regarded as one of the most hazardous aspects of the construction site. According to the OSHA regulations (CFR1926 Subpart M), fall prevention must be implemented at all elevations above six feet. It might be inferred that the implementation of fall prevention techniques might be lacking or inadequate on these lower elevation projects.

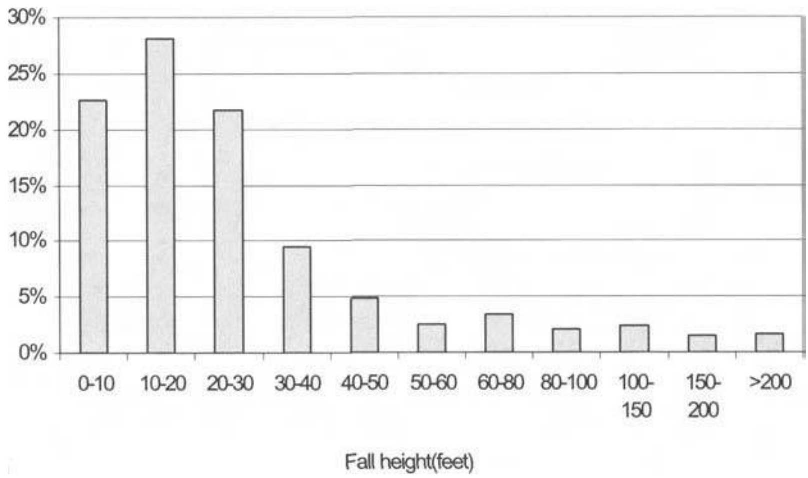

Fig. 1.3 Distribution of the height of construction fall accidents (01/97-10/01)

INJURIES RESULTING FROM ALL ACCIDENTS

The 2,741 fall accidents resulted in 2,955 injuries. The predominant occupations of the injured workers included construction laborers, roofers, carpenters, structural metal workers, painters, bricklayers and stonemasons, electricians, supervisors, drywall installers, plumbers and pipefitters. The types of fall injuries that are most common include fracture, concussion, and bruise/contusion/abrasion. Half of the injuries were head injuries, and about one third were multiple injuries. Fall injuries frequently involve injury to the chest, neck, back, abdomen, and legs. Regarding the severity of injuries, two-thirds Regarding the severity of injuries, two thirds of the workers involved in falls were killed, emphasizing the serious nature of fall accidents.

The ages of workers most frequently involved in falls are between 31 and 40, with the overall average age being 38.3. This is similar to the distribution of the ages of workers involved in other types of injuries. If the frequency of falls is calculated for different age groups, it is apparent that the proportions of age groups below 35 are lower than for those above 35. This may suggest that experience in construction may not necessarily lead to a decrease in fall accidents or that younger workers tend to be more alert and flexible when fall hazards occur.

CAUSES OF FALL ACCIDENTS

Work tasks and fall occurrence

Falls may be associated with the particular work tasks being performed. This was examined in this study. Table 1.4 shows the most frequent types of tasks performed when fall accidents occurred. It was noted that the most common work tasks included roofing, erecting structural steel and exterior carpentry. Most of the tasks were conducted at elevation or on temporary structures, where fall hazards are often present. Falls occurred at relatively low elevations. About 75% of the roofing worker falls occurred at elevations of less than 30 feet, and 45% were less than 20 feet. Workers on these projects may underestimate or ignore the fall hazards at these seemingly low elevations. To avoid falls, any work done above 6 feet should be performed with care and with the appropriate fall protection.

Table 1.4 Distribution of injuries by type of work being performed

Work Activity	Falls	
	Count	Percent
Roofing	252	21.6%
Erecting structural steel	99	8.5%
Exterior carpentry	89	7.6%
Exterior masonry	57	4.9%
Installing equipment (HVAC, etc.)	54	4.6%
Demolition	53	4.5%
Other	561	48.2%
Subtotal	1165	100.0%
Not Known	50	
Total	1215	

Location of falls

Over half of the fall injuries are related to environmental factors involving the working surface or facility layout conditions. Falls from roofs are the most frequent accidents, especially in commercial buildings and single family or duplex dwelling projects. Most falls took place from roofs, from/with structures, from/with scaffolds, from/with ladders, and through openings (see Table 1.5). These account for about 80% of all construction fall accidents. Provision of adequate preventive equipment in these locations is essential to avoid falls.

Table 1.5 Distribution of injuries by type of work being performed

Work Activity	Falls	
	Count	Percent
Fall from roof	333	28.4%
Fall from/with structure (other than roof)	227	19.3%
Fall from/with scaffold	153	13.0%
Fall from/with ladder	133	11.3%
Other	328	27.9%
Subtotal	1174	100.0%
Not Known	41	
Total	1215	

Human errors resulting in falls

Analysis of human errors showed that misjudgment of the hazardous situation is the most frequent type of human error involving falls, accounting for about one third of all the accidents. The distribution of misjudgment for different ages is roughly similar to the age distribution of fall injuries, except for the age group between 21 and 25 where a disproportionate number of falls are the result of misjudgment (see Fig. 1.4). Human errors categorized as "misjudgment of hazardous situation" account for about 30 percent of the falls. It is possible that age or experience do not noticeably improve judgment where hazardous situations are concerned. Results suggest that workers between the ages of 21 to 25 should be trained and educated about fall hazards. Of course, it must be recognized that the "misjudgment of hazardous situation" is a subjective assessment and is difficult to quantify or verify.

Further analysis revealed that most falls associated with human errors occurred at lower elevations. For example, more than half of falls related to 'misjudgment of hazardous situation' were less than 20 feet in elevation, and 23.5% of them were less than 10 feet. Falls were also associated with 'insufficient or lack of protective work clothing and equipment' with 40% occurring at elevations of less than 20 feet.

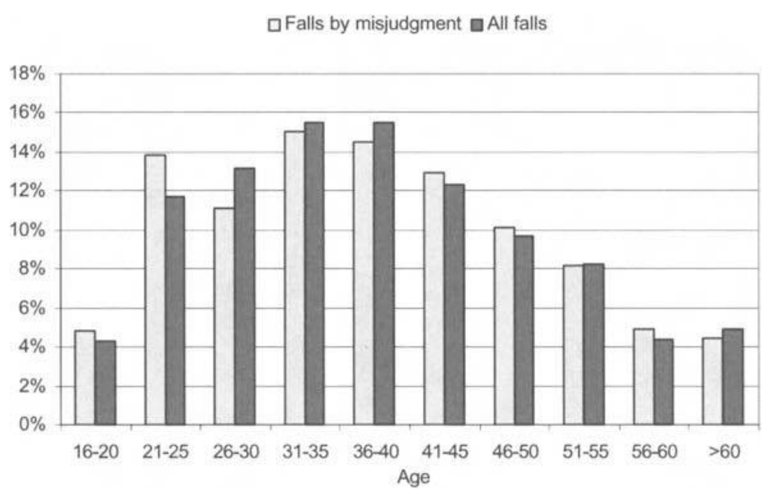

Fig. 1.4 Proportion of falls by misjudgment for different ages (01/90-10/01)

Inadequate or inappropriate use of fall protection (PPE), and removed and inoperative safety equipment contributed to more than 30% of the falls. This situation does not change significantly after 1996, when the OSHA regulations on

PPE were significantly revised. Typical examples include work being performed by workers who are not tied-off. There are also several falls that occurred when a body harness was unhooked to facilitate movement to a different location. Therefore, the adequate provision and proper use of fall protective PPE are necessary to ensure worker safety.

Immediate sources of falls

A contributing factor in one-third of the fall accidents was the working surface. The accidents included typical situations where workers slipped on sloped roofs and fell to the ground, workers fell through floor openings, and workers slipped on the walking surface of scaffolds and fell. Inadequate fall preventive equipment in buildings/structures, and/or failure of buildings/structures also caused some workers to fall. These falls can be effectively prevented by the use of the appropriate fall preventive equipment.

DISTRIBUTION OF FALL ACCIDENTS AND OSHA INSPECTIONS

The states where falls occurred were also examined. The results showed that Texas had the most fall accidents, followed by Florida, New York, California, and Illinois. The Standard Industrial Classification (SIC) codes associated with falls were also examined. The primary SIC codes associated with falls were 1761 (Roofing, Siding, and Sheet Metal Work), 1791 (Structural Steel Erection), 1542 (General Contractors-nonresidential Buildings, Other Than Industrial), 1799 (Special Trade Contractors, Not Elsewhere Classified), 1731 (Electrical Work), and 1711 (Plumbing, Heating and Air-conditioning). The occurrence of falls is clearly related to the type of work performed.

When comparing fall accidents with all construction accidents, the average penalty on fall injuries is higher than on the aggregate of other accidents. For example, the average and median value of the imposed penalty for fall-related accidents were $8,917 and $2,250, respectively. This is in contrast to $7,757 and $1,800 for the overall accidents. It was also found that there are more serious violations in fall inspections than in overall inspections. The Bureau of Labor Statistics (BLS) website (http://www.bls.gov/iif) provided the most frequent citations to Construction Special Trade Contractors (SIC 17), that account for most (about 80%) falls. Nearly half of the citations are associated with fall hazards on the jobsite or the lack of training on falls. Clearly, emphasis on construction fall protection is warranted: scaffolding, ladder, fall protection training, training for scaffolding, and so on.

CONCLUSIONS AND RECOMMENDATIONS

Falls are the most frequent accidents that occur on construction sites. Results show that fall accidents in the construction industry are the cause of many serious injuries and fatalities. At the same time, the data analysis shows that falls have certain properties, which may help to devise preventive approaches.

Many parties have sought means to prevent falls, including OSHA, the construction industry, and various researchers. Some measures do not work as well as others. For example, since the OSHA regulations on PPE for fall prevention were revised in 1996, neither the quantity nor pattern of falls on construction sites has changed significantly. In fact, the proportion of accidents that are caused by falls has actually increased. This may stem from the strong economy that the U.S. construction industry has enjoyed in the years following 1995. The strong economic growth has

resulted in the hiring of many workers, a large proportion of whom may be inadequately trained. Clearly a continued focus on falls by OSHA is well warranted and more training of the workforce is needed as well. It is not clear what the incident rate of fall injuries would have been had there not been a clear focus on fall prevention in recent years.

For the construction industry, fall hazards analysis and communication of related findings are necessary to ultimately impact the occurrence of fall accidents. It was noted that falls commonly occur on projects that can be characterized as being small and relatively low in cost, and involve new construction of commercial buildings and residential projects.

It is evident that many fall hazards go unnoticed or that efforts to prevent falls are not effectively implemented. Fall hazards on sites should be detected through rigorous inspections of construction sites and eliminated through effective preventive approaches. The accumulation of information on previous accidents can disclose the most common hazards on construction sites. Operations particularly susceptible to falls include roofing, erecting structural steel and exterior carpentry. Falls are often associated with workers on roofs, scaffolds, ladders, and on floors with openings. Occupations such as construction laborers, roofers, carpenters, and structural metal workers are commonly involved in falls and should be specifically addressed through fall prevention efforts. Fall hazards mapping, as suggested by Gambatese and Stewart (1999), can serve as a very useful technology to indicate where fall hazards exist.

Through the analysis of past fall accidents, documented fall-related near misses, as well as fall-related citations, the most hazardous locations on sites can be identified. Providing fall preventive equipment to workers, including full-body harnesses, along with the proper training, should reduce the number of falls. The lack of safety training is often the root cause for many falls. According to the analysis, misjudgment of workers may account for about one third of the construction worker falls. Fall prevention training can be effective in addressing numerous causes of accidents. Traditional safety training, restricted to the verbal and manual descriptions of the OSHA regulations, may not be sufficient to enable the workers to detect and eliminate all fall hazards. Innovative training approaches should be explored.

Allan St John Holt (2001, page 159) stated: "fall prevention is far more effective than fall protection, which often involves personal protective equipment. Reliance on people to make the 'right' decision about wearing personal protective equipment has been shown by events to be unsatisfactory – they forget, decide not wear it in view of the expected short exposure time, or do not wear or use it correctly. The first stage in fall prevention is during the design process, which influences the construction method." While addressing worker safety in the design phase is a relatively new concept, it is clear that safer plans, developed through thoughtful design decisions, can decrease the occurrence of falls.

For safety researchers, many topics related to falls need to be investigated in greater detail. For example, the current personal fall arrest systems (PFAS) can effectively protect workers after they fall from elevation. While these may constrain the movement of workers, as with steel erection operations, such approaches should be considered. Motivating workers to fully utilize the safety equipment at all times is perhaps the greatest challenge. Some workers fell because they did not tie-off their body harnesses, either because they felt it was troublesome to be tied off to a fixed anchorage or when they unhooked the lanyards to change their positions. Such practices must change. More flexible PFAS might be able to save more lives. Different kinds of new technology, which can help prevent falls and protect workers from injury by falls, should be developed.

ACKNOWLEDGEMENTS

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Analysis of Safety Issues in Trenching Operations

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ABSTRACT

Trenching related accidents account for a large percentage of accidents in the construction industry. These accidents can be caused by failure of the soil in which the trench was excavated, or the lack of protection of the trench walls by means of structures such as trench boxes or contacts with equipment or materials near the trench area among others.

OSHA (Occupational Safety and Health Administration) inspections are limited to establishing the cause of the trenching related accident and verifying if the required measures, according to their standards, were used. If the required measures to ensure safety were not taken, then OSHA can impose fines to the company performing the work. However, these inspections may not indicate the reasons why the OSHA trench safety standards were not used or why they failed to protect the workers.

This paper will describe a comprehensive analysis of the events leading to the accidents in trenching related work. It will examine those aspects of the trenching operation that are not fully addressed in the OSHA inspections. The paper will provide a synopsis of possible modifications to the existing OSHA standards that could provide alternatives to provide a safe working environment when traditional standards are not feasible or practical to apply. The research study underlying this paper, is funded through a grant from the National Institutes of Occupational Safety and Health (NIOSH) to the Construction Safety Alliance (CSA).

INTRODUCTION

Trenching fatalities and injuries continue to plague the construction industry. While complete and accurate records of the actual number of fatalities occurring in trenching incidents are not maintained, "the estimate of 100 fatalities per year due to cave-ins and other excavation accidents (Hinze and Bren 1996)," and 7000 injuries, is perhaps a reasonable approximation of the magnitude of the problem. Many studies have analyzed accident reports of agencies such as the Occupational Safety and Health Administration (OSHA) and the Bureau of Labor Statistics and determined the various reasons for trenching related accidents (Hinze and Bren 1996, Suruda et al. 1988). These accidents can be caused by soil failure, the lack of protection of the trench walls by means of structures such as trench boxes, etc. A study conducted by OSHA in 1990 that analyzed construction fatalities from 1985 to 1989 determined that seventy-nine percent of trenching related fatalities occurred in trenches less than 15 feet (4.6 meters) deep and thirty-eight percent occurred in trenches less than 10 feet (3.0 meters) deep.

OSHA inspections are limited to establishing the cause of the trenching related accident and verifying if the required measures, according to their standards, were used. However, the OSHA inspections may not include the reasons why the OSHA trench safety standards were not used or why they failed to protect the workers.

If the required measures to ensure trench safety were not taken at the scene of the trenching operation, then OSHA can impose fines on the company performing the work. These fines can increase the cost of construction work by increasing the contractor's insurance costs. Thompson (1982) reported that the cost of excavation failures that result from unsafe excavation procedures add about seven to eight percent to the cost of construction.

In order to determine possible intervention strategies, it is important to learn more about the circumstances under which the accidents occur, and to investigate the relationship between the accidents and the adherence/non-adherence to OSHA Safety Standards. Such an endeavor is pivotal in understanding why applicable standards were not used, or if they were used, why they were unsuccessful in ensuring safety in the trenching operation.

In September 2001, Purdue University, in partnership with the University of Cincinnati, the University of Florida, Gainesville, and the University of Texas, Austin received a grant from the National Institutes of Occupational Safety and Health (NIOSH) to develop, implement and evaluate a national research program in construction safety and health. One of the target areas of study is the Development of Safer Trenching Operations. The general objectives of this study are three-fold:

1. Analyze the causes of accidents in trenching operations.

2. Establish an information database on work risk factors associated with trenching operations.

3. Develop strategies to prevent fatalities and reduce injuries in trenching operations.

This paper presents some initial findings underlying the relationship between the OSHA Safety Standards for Excavation Safety and the causes of trenching related accidents.

OSHA STANDARDS AND EXCAVATION SAFETY

The OSHA (Occupational Safety and Health Act) standard related to trenching (OSHA Standard 1926 Subpart P) consists of three main sections with six (6) appendices. The first section contains definitions clearly defining the terms used in the excavation standard. The second section contains the general requirements. All underground and aboveground installations must be located before starting excavation work. Access and egress must be provided for employees in excavations over 4 feet (1.2 meters) in depth to prevent falls when entering or exiting excavations. Employees working in trenches shall be protected from cave-ins, loose rock and soil, falling loads, and hazardous atmospheres. Both surface and subsurface water must be controlled with water removal equipment supervised by a competent person. Adjacent structures must be underpinned before start of excavation work. All required inspections should be conducted by a competent person on a daily or as-needed basis. Fall protection must be provided where appropriate, in excavations and over trenches.

The third section specifies the actual Requirements for Protective Systems that must be provided by the employer to protect workers who enter excavations. The standard requires that employees entering excavations which are five feet (1.5 meters) or greater in depth be protected from cave-ins. The requirements for protective systems are divided into two categories, *sloping and benching* and *support systems*, *Support systems* include *shoring systems* and *shielding systems.* It must be noted that the competent person can use the standard to a maximum depth of 20 feet (6.1 meters). Excavations deeper than 20 feet (6.1 meters) require the approval of a registered professional engineer.

In 1991 OSHA conducted a study on the most cited standards in the construction industry. The purpose of this study was to identify the causes of accidents and provide suggestions on how to eliminate, control or mitigate such hazards. This study showed that 4 of the top 25 standards cited were related to trenching as shown in Table 1

Table 1 Most cited trenching related standards (adapted from OSHA 1991)

Rank	Description of Standard		Standard (1926.___)
5	Trenching/Excavation	Protective Systems for trenching/excavation	652(a)(1)
11	Trenching/Excavation	Daily inspection of physical components of trench and protection systems	651(k)(1)
16	Trenching/Excavation	Spoil pile protection	651(j)(2)
22	Trenching/Excavation	Access/Egress from trench/excavation	651(c)(2)

ROLE OF THE COMPETENT PERSON

In order to ensure the safe execution of the trench excavation activities in the construction site, OSHA requires the presence of a "Competent Person" during the activity. To function as a competent person at an excavation site a competent person must be (Lew 1994):

- Thoroughly knowledgeable with excavation safety standards including soil classification.
- Capable of identifying existing and predictable and hazards and unsafe conditions.
- Knowledgeable in the proper use of protective systems and trench safety equipment.
- Designated to have the authority to stop work when unsafe conditions exist.

A person must have documented experience and training in the first three requirements, and be designated as the competent person by the employer with the authority indicated in the fourth requirement.

CHARACTERISTICS OF TRENCHING ACCIDENTS

An important source of information related to trenching related accidents is the OSHA investigation reports, which makes up the largest single source for this type of information. To analyze this information a total of fifty fatal and non-fatal cases were identified from 1996 to 1997. The data was obtained from the OSHA

Database System. The following parameters were analyzed, and the observations are discussed in the remainder of this section:

- Month of event
- Accident outcome (injury or fatality)
- Classification of accident by Bureau of Labor Statistics (BLS) code (exposure)
- Gender of workers affected
- Age of workers affected
- Classification by Standard Industrial Classification (SIC) code
- Time of day of accident
- Union status of workers
- Trench characteristics
- Risk factors

Month of Event

In 1996, twenty one percent of the accidents occurred during the month of October. In 1997, eighteen percent of the accidents occurred during the month of December. Overall, the month with the highest incidence of accidents during the period of investigation (1996-1997) was October as shown in Figure 1

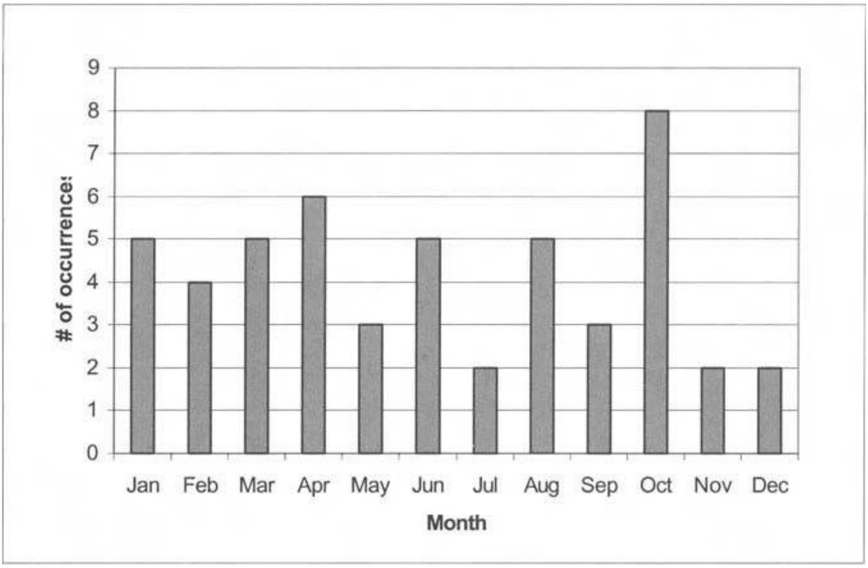

Figure 1 Total occurrences of trenching accidents by month (1996-1997) – From OSHA's Integrated Management Information System (IMIS)

Accident Outcome

Of all the cases studied, more than half (65%) resulted in fatalities and only 35% resulted in injuries. The most cited reason for the accidents resulting in fatalities was excavation or trenching cave-ins. The degree of the injuries varied from sprained muscles to fractures. In most cases, injured workers were treated and released the same day from the hospital because their injuries were not severe. In such cases, the nature of the injury was not reported.

Classification of Accident by BLS Code

Based on the Bureau of Labor Statistics (BLS) Classification System, it was observed that 19 of the 50 cases studied (38%) of the accidents fell under the BLS Code 041 (Excavation or Trenching Cave-in) and that the remaining 62% fell under other BLS Codes (Table 2).

The number of accidents that were categorized under other codes varied from 2% to 8% per code. This shows that there are many dangers related to trenching work and that the majority of the accidents are caused by reasons other that trench cave-in. The following table shows the occurrences of each type of exposure by BLS code.

Table 2 Accident occurrences by BLS Code - From OSHA's Integrated Management Information System (IMIS)

Exposure Code	Description	Occurrences	%
012	Struck against stationary object	2	4%
013	Stuck against moving object	1	2%
0220	Struck by flung object, unspecified	1	2%
021	Struck by falling object	4	8%
030	Caught in or compressed by equipment or objects, unspecified	2	4%
039	Caught in or compressed by equipment or objects, n.e.c.	1	2%
0040	Caught in or crushed in collapsing materials, unspecified	1	2%
041	Excavation or trenching cave-in	19	38%
042	Other cave-in	1	2%
0049	Caught in or crushed by collapsing materials, n.e.c.	4	8%
113	Fall from ladder	2	4%
0239	Struck by swinging or slipping object, n.e.c.	1	2%
313	Contact with overhead power lines	3	6%
319	Contact with electric current	3	6%
1120	Fall from floor, dock, or ground level, unspecified	1	2%
1124	Fall from ground level to lower level	3	6%
384	Depletion of oxygen in other enclosed, restricted, or confined space	1	2%

Gender of Workers

From the data obtained from the OSHA reports, it was observed that all of the workers involved in trenching accidents were male. Due to the dangerous and physically demanding nature of trench related work it is expected that the majority of the workers will be male.

Age of Workers

The mean age of workers involved in the fifty reported trenching accidents during the 1996-1997 time frame was 34 years. The distribution of ages was skewed toward younger ages, the largest group (20) being in the range of 20 to 30 years as shown in Figure 2.

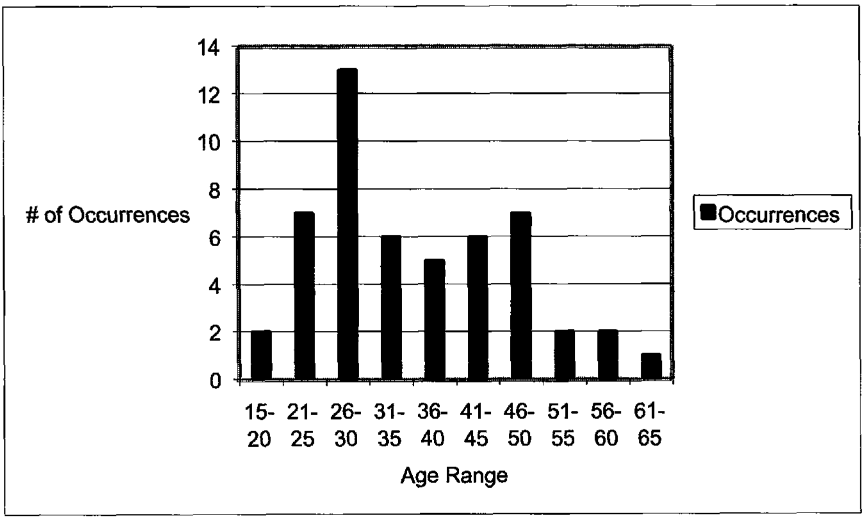

Figure 2 Age Distribution of Workers Involved in Trenching Accidents - From OSHA's Integrated Management Information System (IMIS)

Classification by SIC Code

According to the data from the OSHA reports forty percent of the accidents reported involved workers for water, sewer, and pipeline contractors, i.e., SIC (Standard Industrial Classification) Code – 1623.

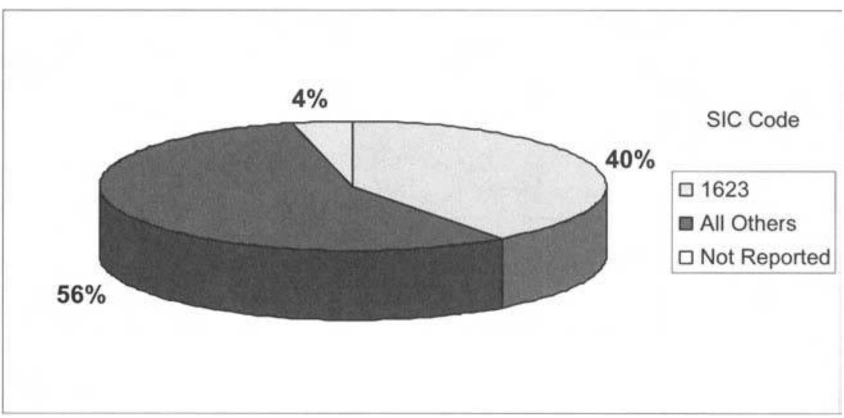

Figure 3 Total accident occurrence by SIC code - From OSHA's Integrated Management Information System (IMIS)

Time of Day

From the data available a comprehensive analysis of the time of day of occurrence of the accidents was not possible. The time of day of the accidents was reported on only seven (14%) of the 50 cases analyzed.

Union Status

The majority of the workers involved in trenching related accidents were non-union workers (98%). The low rate of trenching accidents among union workers could be attributed to the extensive training they receive prior to arriving at the jobsite.

Trench Characteristics

Of the fifty cases studied, twenty-seven reported information related to the depth of the trenches in which the accidents took place. The depth of the trenches varied from 0 to 20 ft (0 to 6.1 meters) with ten instances (37%) in the range from 0 to 5 ft (0 to 1.5 meters) (Figure 4). This gives us an indication that even in shallow trenches the possibility of accidents still exists.

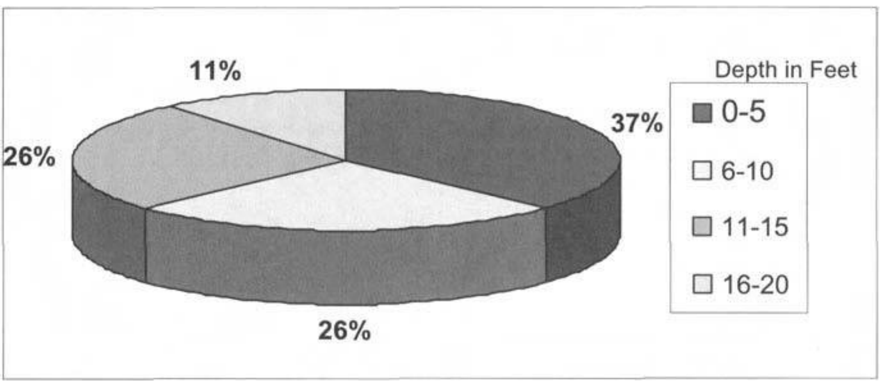

Figure 4 Total accident occurrence by trench depth - From OSHA's Integrated Management Information System (IMIS)

In five cases studied (10% of total number of cases analyzed) the presence of excavation support structures was reported. In eight cases there was no trench support structure present and in thirty-seven of the 50 cases (74% of the cases analyzed) the presence of excavation support structures could not be determined from the OSHA accident reports (as shown in Figure 5). The reporting format used by OSHA can be enhanced to seek such information for determining the causes of trenching related accidents.

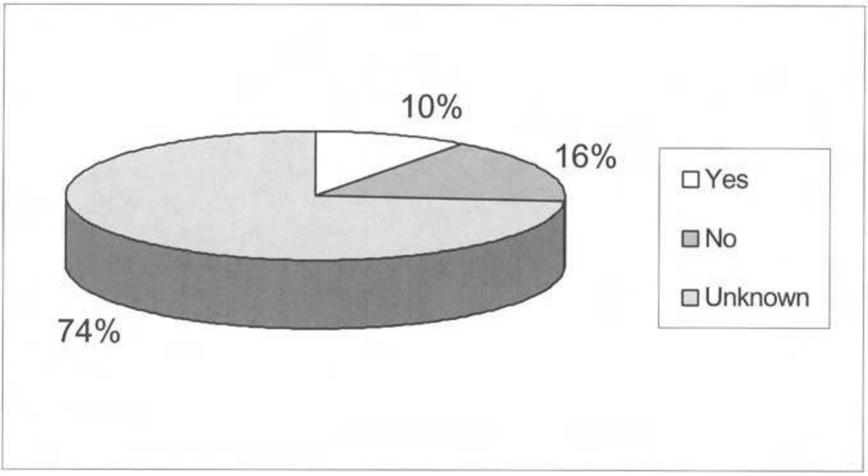

Figure 5 Presence of excavation support - From OSHA's Integrated Management Information System (IMIS)

The type of excavation protection structures or methods depends on the characteristics of the trench. Depth and soil condition are the predominant factor when deciding if and what type of protection will be used. Of the five cases where excavation support structures were present, shoring was used to protect two of the trenches, trench boxes were used in two cases and sloping was used in one case.

Risk Factors

Various risk factors that contribute to trenching accidents (as shown in Table 3) were identified from the OSHA accident reports. Misjudgment of hazardous situations was identified in 39% of the instances, making it the most common risk factor. This reinforces the need to have a "Competent Person" capable of correctly identifying risks so that actions can be taken to reduce the probability as well as severity of accidents.

Table 3 Identified risk factors associated with trenching accidents - From OSHA's Integrated Management Information System (IMIS)

Risk Factor	# of Occurrences	% of total
Unstable soil condition	7	15%
Misjudgment of hazardous situation	18	39%
Inappropriate handling of materials or equipment	8	17%
Overhead load hazard	7	15%
Failure to secure trench walls/ or protection not present	6	13%
	46	100%

SUMMARY

This paper discussed the characteristics of trenching related accidents based on an analysis of OSHA accident reports for trenching accidents that were reported in 1996-1997. The paper also reviewed the actual OSHA standards related to trench safety and the role of the "Competent Person" in trenching related work. Failure of trench walls continues to be the main cause of trenching related accidents in the construction industry particularly when protection systems are not employed. In many cases, the failure to employ such protective systems may be the result of misjudgment of the hazardous situation present at the work site or the lack of a "Competent Person" to make such evaluations. Additional data collection will be necessary to better assess the causes of trench related accidents. Site visits and interviews with craftspeople, and front-line supervisors will be conducted during Spring and Summer 2002 to identify potential intervention strategies.

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Analysis of Trench Shield Injury Accidents

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INTRODUCTION

Trench related accidents, often resulting in serious injuries or fatalities, are a continuing concern in the construction industry. While there are no definitive numbers on the actual number of fatalities involving trench cave-ins, it is suspected that a conservative estimate would place the death toll at over 100 per year.

Whenever workers are working in a trench, especially those with a depth of greater than five feet, some type of worker protection must be provided. This protection can be provided by sloping the trench walls, installing shoring inside of the trench, or by having the workers work inside a trench shield that is placed in the trench. One of these methods of worker protection must be provided. Of these methods, sloping the trench walls is perhaps the most economical approach, but there are limitations as to when this can be done. For example, if a trench is to be dug in a municipal area, sloping the trench walls will not be feasible if the trench is near vehicular traffic-ways or near buildings. Supporting the trench walls with shoring is perhaps the most logical approach under such conditions. Shoring the trench is the traditional method that has been used successfully for many decades. There are few noted incidents of trench cave-ins where shoring was actually employed in the trench. Of course, shoring is an expensive approach and is probably avoided by some construction firms for that reason. The use of trench shields or trench boxes offers a viable alternative to provide for the protection of the workers inside trenches.

Trench shields have been used for a number of decades to provide protection for workers in trenches. Despite the apparent protection offered by trench shields, workers still die in trenches when trench shields are used. There are over 100 noted accidents in which fatalities or serious injuries have occurred where trench shields were being employed. This paper presents the results of a review of these accidents. The objective was to identify the root causes of the fatalities that occurred when trench shields were being used. Knowing the root causes would give insights as to how future trench shield accidents might be prevented.

BACKGROUND INFORMATION ON TRENCH SHIELDS

Trench shields, also widely referred to as trench boxes in the construction community, consist of two large steel plates that are separated by heavy spreader bars. The steel plates are reinforced with additional steel stiffeners. The spreader bars are generally adjustable so the width of separation of the trench shield plates can be modified to conform to the width of the trench. The ends of the trench shields are often open, but bulkheads can be installed if conditions warrant this. Ideally, the width of the trench shield should be such that it will fit easily into the trench, but with only a small annular space between the sides of the trench shield and the trench walls. If a cave-in does occur, the trench shield is designed to withstand the lateral earth pressures.

The trench shield is designed for worker safety. As long as workers are in the trench shield, they should be safe from harm, provided that all proper safety precautions are exercised. Trench shields are well suited for use in pipelaying installations. The trench shield must be at least as long as the length of pipe being installed. Ideally, the trench box should be longer than the length of pipe so it can be easily lowered into the trench shield without striking the spreader bars and also to provide safe space for workers in the trench as the pipe is being lowered. Once the pipe joint is completed, the operation will then focus on the installation of the next length of pipe. This is where the trench must first be extended by digging additional trench length. After the trench extension is dug, the trench shield is moved forward. The hydraulic excavator that is used to dig the trench is typically also used to advance the trench shield to the next position. This is done by bringing the bucket of the hydraulic excavator over the top spreader bar of the trench shield and pulling the trench shield forward. Because of the weight of the trench shield, moving the trench shield is often the most arduous work that must be performed by the hydraulic excavator. Pulling the trench shield forward is more difficult if a cave-in does occur as this will "pin" the trench shield in the trench. Some trench shields are designed with a slight taper whereby the trench shield is narrower toward the rear. This makes it easier to pull the trench shield forward in the event of a trench cave-in.

The Occupational Safety and Health Administration (OSHA) regulations for trenching requirements are located in the 29 Code of Federal Regulations, Part 1926 Subpart P - Excavations. The initial OSHA regulations acknowledged that trench shields were used in the construction industry, but only made a brief mention of them. The OSHA regulations defined trench shields as, "A shoring system composed of steel plates and bracing, welded or bolted together, which support the walls of a trench from the ground level to the trench bottom and which can be moved along as work progresses." In reality, in normal operations, the trench shield does not "support the walls of a trench" but rather has the ability to support trench wall pressures in the event of a trench collapse. The only other specific mention of trench shields in the OSHA regulations was a statement that, "Portable trench boxes or sliding trench shields may be used for the protection of personnel in lieu of a shoring system or sloping. Where such trench boxes or shields are used, they shall be designed, constructed, and maintained in a manner which will provide protection equal to or greater than the sheeting or shoring required for the trench."

OSHA did recognize that trench shields might be an effective means of providing for worker protection in trenches. This was apparent in the illustrated 1975 brochure that OSHA published, entitled Excavating and Trenching Operations. In this brochure it was stated that, "Contractors also may use a trench box, a prefabricated movable trench shield composed of steel plates welded to a heavy steel frame. OSHA standards permit the use of a trench box as long as the protection it provides is equal to or greater than the protection that would be provided by the appropriate shoring system."

Although OSHA recognized that trench shields, or trench boxes, were viable means of providing for worker protection, little or no information is offered on safe work practices associated with the use of trench shields. This lack of focus on trench shields may not have been well founded. What was the extent of trench shield use during the 1970s? In a nationwide study in which 90 utility contractors responded, 31 percent of the contractors stated that trench shields were used from 25 to 100 percent of the time. Interestingly, these firms also reported lower OSHA recordable injury rates than those respondents who used trench shields less than 25 percent of the time (Hinze and Carino). From that study it was also determined that most trenches are sloped instead of using shoring or trench shields. In fact, 43 percent of the contractors stated that sloping was used on more than 60 percent of their trenches. OSHA's attention to sloping the trench walls was justified, but a greater treatise on trench shields does seem to have been warranted.

The current OSHA standards address trench shields slightly more than did the initial standards. Some of the most salient regulations specifically related to the use of trench shields include the following:

- Trench shields must be capable of resisting the lateral earth pressures
- Trench shields must be installed so lateral movement of the shield is restricted
- Employees must be protected from cave-in when entering and exiting trench shields
- Employees are not allowed in trench shields while they are being installed, removed, or moved vertically

- The trench bottom is to be no more than 2 feet deeper than the bottom of the trench shield

- The trench shield shall extend no less than 18 inches above the top of the vertical trench walls

RESEARCH METHODOLOGY

The objective of this study was to identify the primary causes of accidents in which trench shields were involved. The causes were assumed to be related to the inadequacy of the OSHA regulations to properly address safe work procedures associated with trench shields or the failure of workers to comply with the OSHA regulations. Identifying the nature of the root causes of trench shield related accidents would provide information with which procedures could be put in place to reduce these types of accidents.

OSHA maintains a database of its investigations involving accidents in which workers are seriously injured or killed. This database was used in this study to investigate trench shield accidents. The Region 10 OSHA personnel in Seattle provided the database to the researchers to conduct this study. This included accidents involving trench shields that occurred in the period from 1984 to 2001. The abstracts written by the OSHA compliance officers were the primary source of information to identify the root causes of the accidents. Cases were not included in the analysis when the information was too vaguely stated to convey the true nature of the cause of the accident.

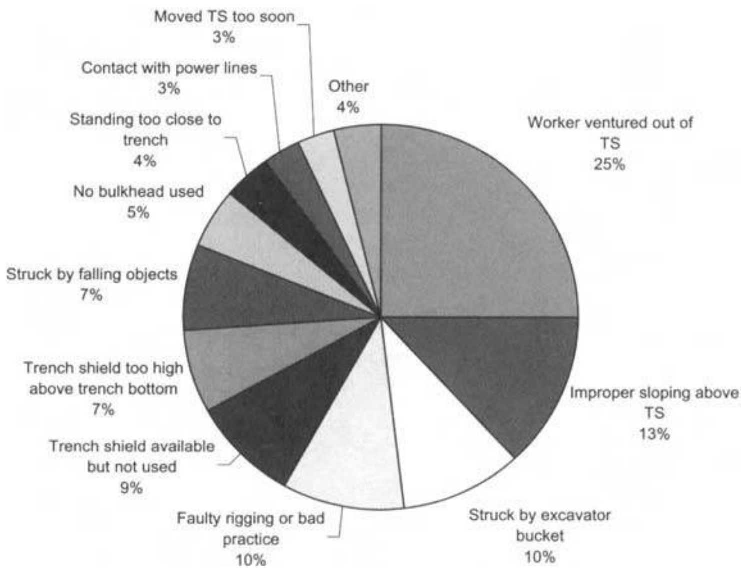

Figure 1. Root Causes of Trench Shield (TS) Accidents

The examination of the data resulted in identifying 114 accidents in which trench shields were involved in some way. Of the 114 accidents, 67 accidents or nearly 59 percent involved fatalities. Although trench shields are generally regarded as providing excellent worker protection against cave-ins, it is evident that serious injuries still occur when trench shields are employed. While 85% of the trench shield accidents resulted in single injury/fatality cases, there were 15 accidents in which two workers were killed or injured in the same incident and in two accidents where three workers were involved.

CAUSES OF TRENCH SHIELD INJURY ACCIDENTS

The primary objective of this research effort was to identify the root causes of the trench shield accidents. An examination of the information provided with each accident record revealed that the accidents could be grouped into eleven different root causes (See Figure 1). An additional category called "other," accounting for four percent of the accidents, could not easily be included in the primary groupings. The eleven root causes, accounting for over 95 percent of the accidents, will be described to a greater extent.

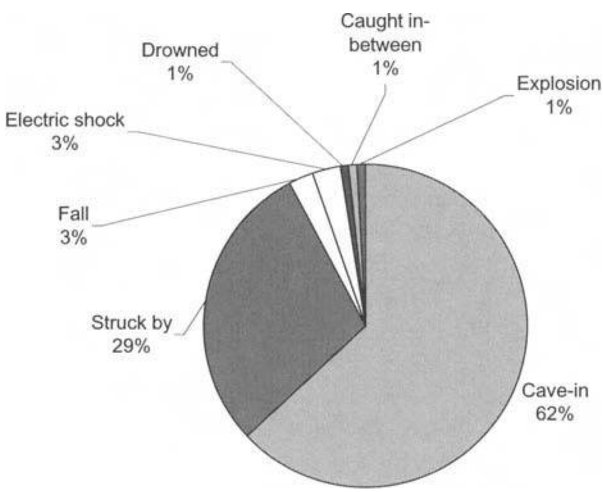

Figure 2. Types of accidents involving trench shields

While most accidents (62 percent) with trench shields involved cave-ins, there are some exceptions. The nature of these accidents is shown in Figure 2. From this figure it is apparent that cave-ins and struck by accidents account for 91 percent of these accidents.

Venturing out of the Trench Shield

Of the 114 accidents that involved trench shields, 25 percent were the result of workers venturing out of the protection of the trench shield. In some cases, workers apparently left the protection of the trench shield to check on a pipe just laid, to retrieve a tool that had been left behind, or they simply ventured into harms way to exit the trench. According to the OSHA regulations, the workers should be provided with a ladder to exit the trench. When working within a trench shield, the workers should be provided with a means of exit, as with a ladder attached to the inside of the trench shield. Workers may have ignored the hazards posed by the trench walls when venturing out of the protection of the trench shield. Obviously, strict compliance with the OSHA regulations would dictate that workers cannot leave the protection of the trench shield for any reason.

Trench Shields set too Low

The OSHA regulations are very clear on the requirement that trench shields are to be placed in trenches but never to a depth where less that 18 inches of the trench box extends beyond the top of the vertical trench wall. This requirement is to prevent trench boxes from being set too deeply within a trench where materials from the trench wall can actually fall in from the top of the trench shield. Of the trench shield accidents, 13 percent were attributed to trench shields being set too deep within the trenches. In deep trenches, it is clear that trench shields must of necessity be set low in the trenches. If the trench is deeper than the height of the trench shield, the trench shields can actually be stacked on top of each other to continue to offer the type of protection that is needed in deep trenches. There were no cases found where trench boxes were actually stacked on top of each other.

Trench Shields set too High

The OSHA regulations state that the bottom of the trench shield cannot be more that two feet above the bottom of the trench. This regulation recognizes that trench shields are not ideally placed at the bottom of the trench. If the trench shield were to be placed so it rests at the bottom of the trench and backfill was then placed around the pipe just laid, there is a possibility that the pipe joint might be pulled apart when the trench shield is advanced. For obvious reasons, the trench shields might be placed above the bottom of the trench. At the same time, the trench shield cannot be higher than two feet above the bottom of the trench. If the trench shield were to be placed higher in the trench, there is an increased chance of a cave-in occurring below the bottom portion of the trench shield. The results of the study show that seven percent of the trenching accidents were a direct result of trench shields being placed too high in the trench. In effect, this is where an unprotected trench is created below the trench shield.

Materials Handling and Equipment Operations

Some of the accidents involving trench shields did not entail cave-ins. In 17 percent of the cases, injuries or fatalities resulted when pipes or other materials were being lowered into the trench shields. Most of these cases were the result of faulty rigging that caused materials to get loose and fall, striking workers in the trench shield. Other accidents occurred whereby the worker or workers were struck by objects, other than falling objects. These generally consisted of materials (usually lengths of pipe) being lowered in the trench and then being placed into some type of lateral motion by a cave-in. The movement of large pieces of pipe is then unopposed within the trench shield. Workers struck by large pipe lengths that were set in motion by such means were generally fatally injured. In addition to being struck by materials, another ten percent of the accidents were the result of workers being struck directly by the excavator bucket. These were often fatal and were probably the result of the operators not being fully aware of the location of the workers or they may have occurred when workers ventured too close to the digging operation.

Trench Shield Available but Not Used

Ten cases (nine percent) were noted in which trench case-in accidents occurred due to no worker protection in the trenches, but where trench shields were on the jobsite but were not being used. This is an unfortunate circumstance as the protection that would possibly have saved the lives of workers is simply permitted to sit idly next to the trench. There is no explanation or justification for this type of negligence.

No Bulkheads Used

Many trench shields are open at the front and back ends. The front is open primarily to permit the excavator bucket to grab the trench shield to pull it forward and to provide some visibility to the operator of the conditions inside the trench shield. The back of the trench shield may be left open to allow workers to exit the trench shield. If workers exit by the back of the trench shield, the workers will generally be exposed to a greater risk of a cave-in. In any case, the lack of a bulkhead may also expose workers inside the trench shield to danger if a cave-in occurs as workers venture too close to the ends of the trench shield. Bulkheads are more practical on the rear end of trench shields, as they might interfere with the ability to advance the trench shield if placed toward the front. Safety is not always adequately addressed as five percent of the accidents involving trench shields consisted of cave-ins that injured workers from the end of the trench shield, generally at the back end.

Standing Too Close to the Trench

While trench shields are ideally placed in trenches that have essentially vertical trench walls, there is typically a small annular space between the outside of the trench shield and the trench wall. This space permits some subsidence to still occur. In four percent of the accidents involving trench shields, individuals stood too close to the edge of the trench. The accidents occurred when the trench wall suddenly collapsed with the excess load. While the trench box provides support to prevent exposure to the workers inside the trench shield, the subsidence of the edge of the trench still can result in workers losing their balance and falling, often into the trench shield. Common sense would dictate that a reasonably safe distance be kept between the individual and the edge of the trench. Since surcharge piles are to be no closer than two feet from the edge of the trench, this would appear to be a reasonable guide to use when standing next to a trench shield.

Contact with Power Lines

Overhead power lines are a problem on many construction sites. The potential threat is well known. On projects involving trenching, they pose a problem primarily when the working operation passes underneath power lines. Three percent of the accidents involving trench shields consisted of power line contacts. A typical accident is one in which the boom of the hydraulic excavator contacts an overhead power line as material is being lowered into the trench shield. The electrical shock occurs when a continuous path is made for the electricity to pass from the power lines, through the worker and to the ground. There are numerous options that should be considered when working near such power lines. At the very least, a spotter should be assigned to give guidance to the operator.

Moved Trench Shield Too Soon

Timelines and deadlines often pace construction work. This can result in undue pressures to meet the construction schedule. Safety may be compromised if too much pressure is imposed on meeting the schedule. While the nature of the schedule status was not disclosed in the OSHA records, the actions of some excavator operators indicate that schedule pressures may alter normal operating procedures. For example, in three percent of the cases, the trench shields were moved prematurely. This may occur when the excavator operator has dug the trench in front of the trench shield and begins to advance the trench shield. This might be done despite the fact that some work still remains to be done by the workers inside the trench shield. Advancing the trench shield may force workers to finish their tasks outside of the protection of the trench shield. This is an unfortunate practice as the purpose of the trench shield is lost when this occurs.

Other Root Causes

The remaining three percent of the accidents did not have any clear similarity with any of the other categories of accidents described. For example, one accident occurred when gas that accumulated in the trench was suddenly ignited, resulting in an explosion. In another case, a worker slipped and fell within the trench shield while ascending a ladder in the trench. This worker fell backwards and struck his head on the opposite wall of the trench shield. In another accident, the annular space between the trench shield and the trench wall was quite large. When the trench wall collapsed, the trench shield moved laterally and pinned the worker between the trench shield and the large diameter pipe being laid. While these accidents were very different in nature, they would also appear to be preventable.

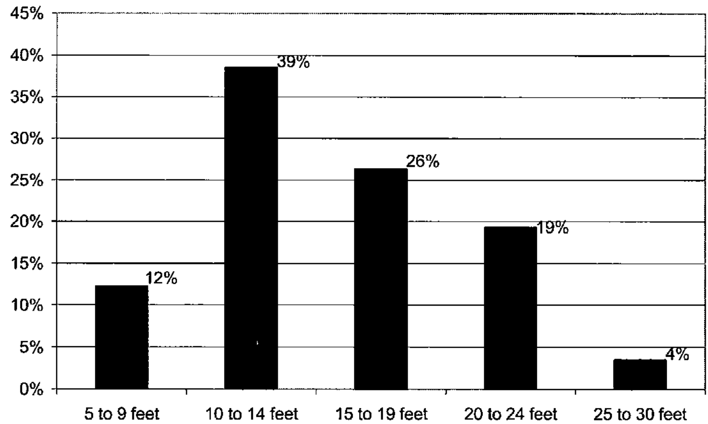

Figure 3. Frequency of accidents at different trench depths

OTHER INFORMATION RELATED TO TRENCH SHIELD ACCIDENTS

Depth of Trench at Time of Trench Shield Accident

The depth of the trench is not information that is reported in each trench shield accident. Half of the cases included trench depth information. This information is summarized in Figure 3. From this information, it can be concluded that over 50 percent of the accidents occur in trenches that are less than 15 feet deep. It should be noted that trenches over 15 feet deep are probably not well suited for trench shield applications unless the trench shields are stacked. While trench shields can be stacked, there was no indication that this was done in any of the deeper trenches in which accidents occurred.

Length of Trench at Time of Trench Shield Accident

The length of open trench at the time of the accident was recorded for only 21 trench shield accidents. While no definitive conclusions can be drawn from such limited data, this can still provide some information that helps to profile information about accidents in which trench shields are involved. The accident frequency by trench length can be broken down as follows:

28.6%	5 to 20 feet
23.8%	21 to 30 feet
23.8%	31 to 50 feet
23.8%	51 to 130 feet

In general, it can be stated that trenches involving trench shields are not very long. Sufficient length of trench must be open in order to accommodate the length of pipe to be laid and, to permit it to be tied into the previously laid length of pipe. The trench length will then be determined by the extent that the backfilling operation keeps up with the pipelaying operation.

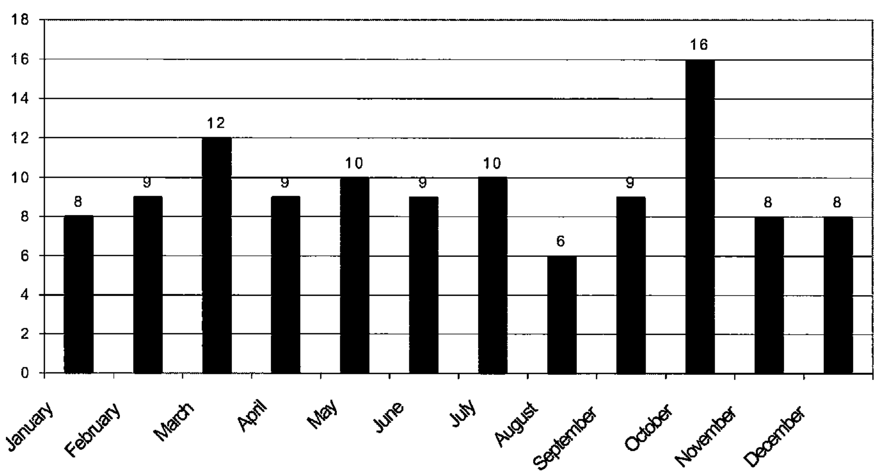

Figure 4. Frequency of trench shield accidents by month

Month of Trench Shield Accident Occurrence

The cave-in accident records were examined to determine if a pattern existed with cave-in occurrence in terms of the month of the year. Most of the cave-ins appeared to be fairly uniformly distributed throughout the year. For the 114 cases examined, the average number of trench shield accidents per month was 9.5. For most months, the frequency of accidents was near this mean value. The only clear anomaly was the month of October in which a total of 16 trench shield accidents occurred (See Figure 4). There is no obvious explanation as to why more accidents occur during October. Perhaps October is one of the wetter months of the year resulting in ground conditions in which cave-ins are more prevalent. It may also be possible that more trenching work is done during the month of October, but this cannot be validated.

Types of Work Performed and Trench Shield Accident Occurrences

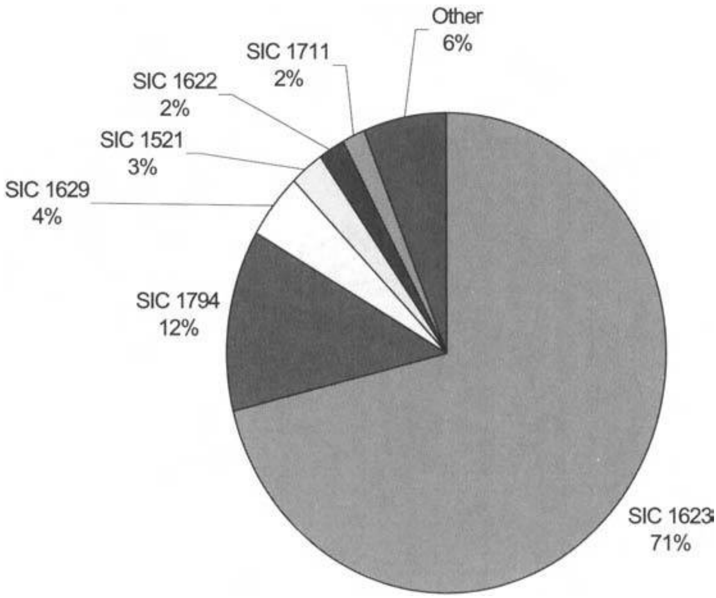

Figure 5. Frequency of trench shield accidents by SIC category

The OSHA records include information on the Standard Industrial Classification (SIC) of the firms with trench shield accidents. Over 70 percent of the firms had an SIC code of 1623 which includes firms involved in water, sewer, pipeline and communications and power line work (see Figure 5). Other categories which had several trench shield accidents included SIC 1794 (excavation work), SIC 1629 (heavy construction, not elsewhere classified), and SIC 1521 (general contractors-single-family houses). These four categories accounted for 90 percent of all accidents involving trench shields. Other SIC categories were involved in accidents but only with one or two accidents each.

Trench accidents are obviously associated with trenching operations and these are generally related to pipelaying operations. The SIC codes associated with trench shield accidents are self-explanatory. Similarly, the types of crafts involved with trench shield accidents are also as expected. The trades of the workers involved in trench shield accidents were specifically noted in only 40 accident records. Of these the following crafts were involved:

Laborer	48%
Plumber, pipefitter	30%
Operator	13%
Supervisor	5%
Truck driver	3%
Structural metal worker	3%

There are various crafts involved in pipelaying operations. All of them play differing roles in the pipelaying operation.

Age of Workers Involved in Trench Shield Accidents

The age of workers involved in the trench shield accidents was provided in each of the accident records. This information is shown in Figure 6. The distribution of accidents by age of worker closely follows the age distribution of workers in the construction industry, with one possible exception, namely the higher incidence of accidents involving workers in the 46 to 50 year-old age category. Any attempt to explain this phenomenon would be speculative as there is no known practical way to assess the type of risk exposure for the different age categories.

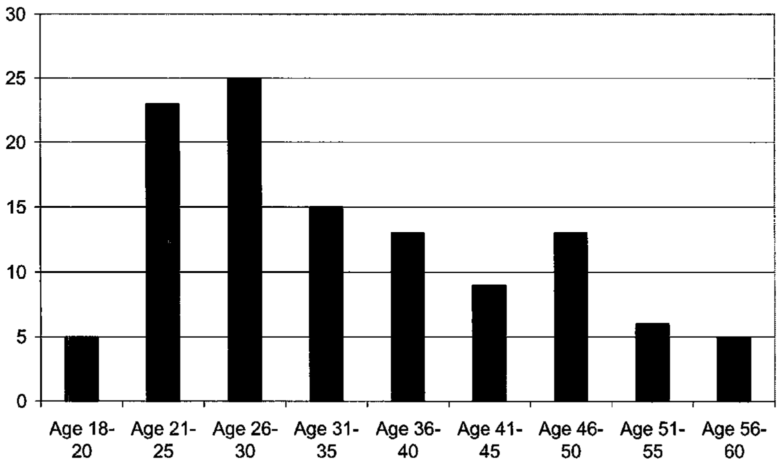

Figure 6. Frequency of trench accidents by age

CONCLUSIONS

The analysis of accidents involving trench shields reveals that trench shields appear to give relatively good protection to workers in trenches. Of all trench cave-in accidents reported in the OSHA database, trench shields are involved in less than ten percent of the accidents, while the extent of use of trench shields appears to be disproportionately higher. When examining the types of accidents involving trench shields, it is apparent that the OSHA regulations regarding trench shields appear to be adequate. Most trench shield accidents are the result of the failure to comply with the OSHA regulations. It does appear that the OSHA regulations related to trench shields are adequate to provide for worker safety. Prevention of accidents related to trench shields would lie primarily in following good work practices and in complying with the OSHA regulations.

RECOMMENDATIONS

Trench shields should be considered for use whenever sloping is difficult and shoring is inefficient. Furthermore, when using trench shields, it is important to always follow the OSHA regulations related to trenching and trench shields. Perhaps the best way to ensure compliance with the OSHA regulations is to thoroughly train workers in the proper practices to follow when working with trench shields. Of course, there is also a need for upper management to fully enforce compliance with the OSHA regulations.

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Safety Management in the Electrical Contracting Industry

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ABSTRACT

The purpose of the research study described in this paper was twofold: (1) to determine jobs/tasks associated with current injury, illness, and fatality trends in the electrical contracting branch of the construction industry, (2) and to identify current safety practices associated with the prevention of these injuries, illnesses, and fatalities. In order to achieve these objectives, a survey was designed and sent to Michigan electrical contractors. To design an adequate survey, the research team first collected background information using United States Bureau of Labor Statistics (BLS) database, published research, and contractor interviews. The results of this study are presented and discussed.

INTRODUCTION

Electrical contractors primarily employ electricians. There were roughly 656,000 electricians in the United States in 1998, and approximately two-thirds of these were employed in the construction industry. Approximately 10% of electricians are self-employed Tao 1997). Electricians perform a variety of functions related to a structure's electrical system. They are involved in the installation, testing, maintenance, and connection of electrical systems. Electricians also work with machinery electronic controls. Electrical contractors can be broadly subdivided into two primary categories: outdoor and indoor. Outdoor work typically involves high voltage wiring from the community to the consumer. Indoor work involves installing conduit, connecting wires, testing circuits, and lighting system installation and maintenance. Electricians are usually required to be licensed, and typically must pass an examination to acquire their licenses. Electricians use a variety of hand tools, including screwdrivers, pliers, knives, hacksaws, power tools, and testing equipment. Some common safety and ergonomic concerns for electricians are electric shock/electrocution, cuts, and falls. Also, the work environment may sometimes involve confined or cramped spaces.

THE BUREAU OF LABOR STATISTICS

Using the United States government's Bureau of Labor Statistics (BLS) safety and health statistics, nonfatal injury and illness data was collected from 1992 to 1998 (BLS 2000). Statistics related to electrical contracting were collected, as well as data on the construction industry as a whole. The four primary set of statistics collected were Sources of Injuries and Illnesses, Natures of Injuries and Illnesses, Parts of Body Affected in Injuries and Illnesses, and Events or Exposures of Injuries and Illnesses. Each specific set will be further discussed in following sections. The various data sets were compiled over the seven-year span for a comprehensive cumulative review, and represented in graphical format (Abudayyeh 2002).

Nature of Injuries And Illnesses

The first primary statistics data set addresses the incidence rates for nonfatal occupational injuries and illnesses involving days away from work by selected natures of injury or illness. The nature of an injury or illness is defined as the principle characteristic of the disabling condition (BLS 2000). The BLS has broken the various natures into 12 major categories: Sprains, Strains, Amputations Fractures, Carpel Tunnel Syndrome Cuts, Punctures, Tendonitis Bruises, Multiple Tramatic Injuries and Disorders Heat Burns, Back Pain and Pain, Except Back Chemical Burns, and All Other Natures. The most prevalent type of injury or illness in electrical contracting was found to be sprains and strains. They accounted for 37% of the total cases. Cuts and punctures were the next largest category, accounting for 13% of the total cases. Fractures were the third largest category with 9% of the total cases. This data fell in line with the overall construction industry averages.

Parts of Body Affected

The second statistical data set reviewed was the incidence rates for nonfatal occupational injuries and illnesses involving days away from work by part of body affected. The BLS divided the body into seven main areas. These major areas are the head, trunk, upper extremities, lower extremities, body system, multiple body parts, and all other body parts. These categories are then further subdivided into more specific areas. For instance, the major category upper extremities are further divided into the subcategories: wrist, hand, finger, and other parts of upper extremities.

Thirty-three percent of electrical contracting injuries and illnesses affected the trunk area of workers. Injuries and illnesses to the upper and lower extremities were very frequent, accounting for 22% and 21% of the cases, respectively. With regard to the subcategories, the back was the most frequent area involved, accounting for 22% of all electrical work injury and illness cases. The knees (8%), fingers (8%), and eyes (7%) were all found to be areas of prevalent injuries and illnesses. Overall, the primary parts of the body affected are the eyes, knees, fingers, and back for both disciplines. The data is also similar to that of the entire construction industry.

Sources of Injuries And Illnesses

The third statistical data set reviewed was the incidence rates for nonfatal occupational injuries and illnesses involving days away from work by selected sources of injury or illness. BLS defines the source of injury or illnesses as, "the object, substance, exposure, or bodily motion that directly produced or inflicted the disabling condition cited" (BLS 2000). The sources of injuries and illnesses were divided into 10 major categories: Chemical and Chemical Products, Machinery Containers, Parts and Materials Floors, Walkways, or Ground Surfaces, Vehicle Furniture and Fixtures, and Worker Motion or Position. The largest source of electrical contracting injuries and illnesses was parts and materials, accounting for 25% of the total cases. The next two largest sources of injuries and illnesses were floors, walkways, or ground surfaces and worker motion or position, at 19%, and 14% respectively. For the most part, the electrical contracting averages are very similar to construction industry data.

Events or Exposures

The fourth statistical data set reviewed was the incidence rates for nonfatal occupational injuries and illnesses involving days away from work by selected events or exposures of injury or illness. BLS defines an event or exposure as "the manner in which the injury or illness was produced or inflicted" (BLS 2000). The types of events and exposures have been divided into 11 main categories: Contact with Objects, Exposure to Harmful Substance or Environment Fall to Lower Level, Transportation Accidents Fall on Same Level, Fire and Explosions Slips or Tips Without Fall, Assaults and Violent Acts Overexertion, All Other Events, and Repetitive Motion. When computing this data, falls to a lower level and falls on the same level were combined and simply termed "falls". This was done in an attempt to simplify the data set.

Contact with objects was the largest category for electrical work injurries, accounting for 22% of the total injuries and illnesses. The second largest categories were overexertion at 22%, and falls at 20%.

Fatal Injuries

The construction industry reported the largest number of fatal work injuries of any industry and accounted for nearly one-fifth of the fatality total in 1998 (BLS 2000). Falls were the most frequent fatal event in construction from 1993 to 1998, accounting for 31% of all cases. Transportation incidents (26%), contact with objects and equipment (19%) and exposure to harmful substances and environments (18%) were all significant fatal events and exposures as well.

Electrical contracting statistics show a significant difference from the rest of the construction industry. Fifty percent of the fatalities during the 1993-1998 period were attributed to the exposure to harmful substances or environments classification, while the entire construction industry attributed only 18% of its fatalities to this classification. Exposure to harmful substances or environments is subdivided into several categories: contact with electric current, contact with overhead power lines, contact with extreme temperatures, exposure to caustic, noxious or allergenic substances, inhalation of a substance, oxygen deficiency and drowning or submersion. Contact with electric current includes events involving machines, tools, appliances or light fixtures, also wiring, transformers and other electrical components. Consequently, these events that are involved with contact with electric current are the most likely to affect electrical contracting workers, thereby resulting in this category's prevalence. Falls and transportation incidents were the other major electrical contracting fatality causes.

SUMMARY AND CONCLUDING REMARKS

The United States Bureau of Labor Statistics data is useful in identifying general areas that warrant further investigation. This paper summarized the results of the study of electrical contracting injuries and fatalities. Construction companies need to be aware of the rather large cost effects an injury, illness, or a fatality can bring upon their business. Contractors often forget that an injury or fatality has effects beyond just the worker in question. There are a great variety of indirect costs that come along with an injury in addition to the costs directly associated with the injured worker. It is important to identify tasks that are most hazardous to the workers. Once they have been identified, a contractor can know where to effectively spend money to improve safety programs and training. Therefore, the task now is to find ways to efficiently reduce or remove the hazards presented in this paper, and then to show contractors how working safely can save them money in the long run.

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Safety Management in the Mechanical Contracting Industry

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ABSTRACT

The purpose of the research study described in this paper was twofold: (1) to determine jobs/tasks associated with current injury, illness, and fatality trends in the mechanical contracting branches of the construction industry, and (2) to identify current safety practices associated with the reduction of risk of these injuries, illnesses, and fatalities. In order to achieve these goals, a survey was designed and sent to Michigan mechanical contractors. Fourteen of the fifty mechanical contracting surveys distributed were completed. The results of this study are presented in the paper.

INTRODUCTION

Mechanical contractors are primarily responsible for installation and maintenance of the mechanical systems of a structure. The mechanical systems of a structure can be classified into five main categories: heating, ventilation, and air-conditioning systems (HVAC); site utilities plumbing; fire protection; and specialty systems. Some mechanical contractors may specialize in only one of these systems, or possibly a subpart of a system, while others may perform a wide variety of services. Since Mechanical contractors may each perform a different variety of services, there is not a single prototypical mechanical contracting worker.

Therefore, the United States Department of Labor lists two main trade groups: plumbers and pipe fitters, and sheet metal workers and duct installers.

There were roughly 426,000 plumbers and pipe fitters in the United States in 1998. Mechanical and plumbing contractors employed approximately two-thirds of these workers. Some common safety and ergonomic concerns listed for plumbers and pipe fitters were: working in tight places, lifting heavy pipes, fall hazards, burns from hot pipes and soldering equipment, and cuts from tools (Bureau 2001). Sheet metal workers and duct installers are also involved in mechanical systems, in that they make, install, and maintain air-conditioning, heating ventilation, and pollution control duct systems. There were roughly 122,000 sheet metal workers and duct installers in the United States construction industry in 1998. Plumbing, heating, and air-conditioning contractors employed approximately three-forth of these workers. Some common safety and ergonomic concerns listed for sheet metal workers and duct installers were cuts from tools, burns from soldering and welding, lifting heavy materials, and falls (Bureau 2001).

RESEARCH METHODOLOGY

Using the United States government's Bureau of Labor Statistics (BLS) safety and health statistics, nonfatal injury and illness data was collected from 1992 to 1998. Statistics related to mechanical contracting work were collected and compared to relevant data from the construction industry as a whole. The four primary set of statistics collected were Sources of Injuries and Illnesses, Natures of Injuries and Illnesses, Parts of Body Affected in Injuries and Illnesses, and Events or Exposures of Injuries and Illnesses (Fredericks 2002). Using this information, an initial survey instrument was designed. Several questions were drafted for each of the body part frequently involved in lost-workday cases. The majority of these questions were phrased so that a body part was identified, and the contractor could identify tasks that were associated with injuries and illnesses to that particular body-part. The survey also contained questions about other significant hazards, such as fatalities, machinery, and hand tools. This preliminary survey instrument was administered to a few local contractors. Based upon the response of these contractors, a two-page survey was designed for mechanical contractors. The purpose of the survey was to identify specific tasks in each field that were frequently involved with injuries, illnesses, or fatalities. The survey was designed to study the most significant hazards and case types, as identified by BLS statistics.

SURVEY RESULTS AND DISCUSSION

Of the fifty Michigan mechanical contractors asked to participate, fourteen completed the survey. This represents a response rate of 28%. The size of the participating companies greatly varied, with some employing as few as 10 workers, and others as many as 700. The participating mechanical contractors worked in residential, commercial, and industrial mechanical system fabrication and installation. The mechanical contracting survey contained 20 questions, with topics ranging from general safety programs to questions about specific injury and illness types. The survey also contained a section in which contractors were asked to rank the frequency at which certain parts of the body were affected with injury and illness. Six parts of the body were listed the knees, back, eyes, feet, hands/fingers, and shoulders. These were all areas of the body that the BLS database indicated were frequently involved with lost workday cases in mechanical contracting. The results of the survey are discussed in the subsections below.

Eye Injuries and Illnesses

The first body-specific section of the survey was concerned with eye injuries and illnesses. Grinding was the primary task for which mechanical contracting workers were injuring their eyes. Approximately 50% of the contractors responding to the survey felt that some of their eye injuries would have been prevented if workers had taken the time to use the proper eye protection. Many of these contractors did remark that workers are frequently injured while wearing eye safety equipment. Properly used goggles may be more effective in reducing the amount of metal shavings that get in to workers' eyes. The second most frequently listed eye injury process was welding. Approximately 53% of the contractors responded that welding created a significant eye hazard. Welding is dangerous to the eyes in two primary ways. First it presents a hazard similar to that of grinders in that there is the risk of foreign objects flying into the eye. Secondly, there is the hazard of "welder's flash" or "arc eye".

Hand/Finger Injuries and Illnesses

The second body-specific section of the survey was concerned with finger and hand injuries and illnesses. Approximately 47% of the participants listed injuries and illnesses to the fingers or the hand as a common injury type in mechanical contracting. There were two primary ways in this type of injury: cuts and burns. Between the two, cuts were more prevalent. Sheet metal was frequently cited as the material involved in injuries. Pipes were also listed as a frequent material causing cuts to hands and fingers. Contractors said that their workers can cut their fingers open on sharp edges of pipes that had been cut to length, or they could smash their fingers when handling the material.

Back Injures/Illnesses

The next body-specific section of the survey was concerned with back injuries and illnesses. Approximately 47% of the contractors listed back injuries as one of the primary ways in which their workers get injured. The participants felt that material handling was the main way in which workers injure their backs. The contractors listed a variety of tools and materials as heavy objects that their workers are typically required to lift. Overall, however, pipes and valves were by far the most common response. A few contractors also mentioned that back injuries occur due to slips, trips, and falls. Poor housekeeping and slippery surfaces, such as ice, were some of the specific inducers of these incidents.

Falls

Falls caused 31% of the occupational deaths in the construction industry from 1993-1998. Of the 14 contractors responding to the survey, 6 said that they have had an employee fall from elevation. More specifically, five of the six said that they had workers who had fallen off a ladder. In one instance a worker was on a ladder on unleveled ground, and the entire ladder fell sideways. The other four responded that their workers had slipped off the ladder. Of the tasks contractors typically have to perform from a raised elevation, pipe and hangar installation was listed most frequently.

SUMMARY

A review of recent BLS data indicated that sprains and strains, cuts and punctures, fractures, and back pain where the most common types of occupation injuries and illnesses in the construction industry. Furthermore, the trunk (back) and upper extremity (fingers, shoulders, and hands) were cited as the most frequently injured body parts. However, the exact causes or tasks associated with these occupation injuries and illnesses remained to be determined. This paper discussed a survey that was designed to answer some of the questions that are not addressed by BLS data. Safe work practices associated with these tasks need to be established and documented so the construction industry can benefit as a whole.

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USING ABSTRACT PRODUCTION MANAGEMENT PRINCIPLES AS A CHANNEL FOR KNOWLEDGE TRANSFER

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"For every person who wants to teach there are approximately thirty people who don't want to learn--much."
W. C. Sellar and R. J. Yeatman:

ABSTRACT

The prospect of continuous reduction of both cost and time, in global transportation and communication encouraged us to study how construction companies could learn better from each other across different regions and countries around the world. This article presents findings of research on the transfer of production practices between Brazilian and English construction sites. The study used "Reduction of Cycle Time", "Reduction of Variability", "Increase of Transparency" and "Continuous Improvement" as the abstract principles for enabling this transfer. The results suggest that abstraction of practices is an effective instrument in enabling knowledge transfer across construction *organisations and countries. Nevertheless, the communication of abstract findings to the workforce in the case study only worked because they had the knowledge presented in a media that suited their learning style and because they were motivated to accept that knowledge. The case study showed that better preparation of the staff with respect to production abstract principles is likely to contribute to speeding up the transfer process.*

Keywords: Knowledge transfer, learning, lean construction

INTRODUCTION

Observation of current practices and literature reveals a growing volume of knowledge about construction practices being transferred across national barriers, through direct communication (e.g.: reports, memos, telephone, video) or group interaction (e.g.: meetings). The expansion of multinational companies, and the continuing migration of people around the world, further accelerates this flow of knowledge (Lemer, 1992; Rebentisch & Ferretti, 1995).

However, international learning across cultures is a complex issue, since it is clearly affected by a large number of variables such as language itself, culture, geography, social rules, political order and even the legal system. These variables create a "distance" or "gap" that is not only physical, but also mental. The larger this "mental distance" the greater the possibility of misunderstandings (Lillrank, 1995). Despite such obstacles, it is clear that the search for better production management elsewhere in the globe has the potential for driving improvements in local practices by stimulating critical reflection.

Intra-sector learning has always been a 'natural' phenomenon amongst construction organisations working in the same region. Seminars, conferences, meetings in professional associations, and even the movement of employees between construction companies, are examples of channels through which knowledge has been flowing across organisations. Cross-sector learning, such as that practised within chambers of commerce, complements the 'natural' intra-sector learning. The manufacturing industry, in particular, has been a good source of innovation and a reference point of production practices for the construction industry.

Furthermore, there is great scope for learning between companies of developed countries from companies in developing countries, and vice-versa. It is also widely recognised that the strategy of buying or copying practices demands resources that are not always available in developing countries. At the same time, imaginative and successful solutions for production problems, developed in the Third World, may indeed be a valuable source of ideas for developed countries.

In this context, the next section discusses a mechanism that, the authors believe, enables a better interpretation and subsequent successful transfer of knowledge, across different companies and different regions across the globe.

ABSTRACTION ENABLING KNOWLEDGE TRANSFER

Production system represents a continuum of 'know-how' ranging from low abstract physical technology to highly abstract concepts. When 'know-how' is only understood as physical technology, its capacity to carry fundamental changes in other contexts is limited. In some situations, this mode of knowledge transfer may not even be technically or economically feasible and the recipient environment may not even have the right materials, machines or personnel to make the new technology to work properly (Barrett, 1997).

Similarly, the successful transfer of a complete managerial methodology, from one place to another, may be extremely difficult, since it is rare to find an environment where complex variables and inter-relationships are equal between contexts. Cultural differences, in particular, have great impact on the knowledge transfer process since they are normally deeply embedded. This usually demands adaptation of ideas from the original managerial technology to the new context (Barrett, 1997).

In this context, Lillrank (1995) proposed that practice would be more effectively transported across different cultures if they were first translated into abstract ideas, as illustrated in **Figure 1**. An abstraction must go beyond the simple description of the directly observable processes and certainly demands a deeper understanding of the meaning and dynamics of processes related to their original context (Lillrank, 1995).

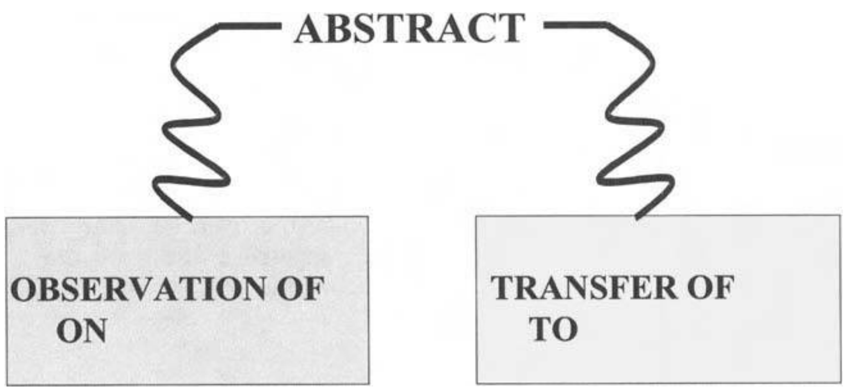


Figure 1 - Abstraction as a Mechanism of Knowledge Transfer (adapted from Lillrank, 1995)

According to this idea the transmission of knowledge is more likely to occur when the essence of a particular practice has been crystallised into what appears to be useful abstract idea that have practical applications in other settings. For instance, only when the Japanese practice of Quality Control Circles (QCC) was properly presented as the principle of "continuous improvement" was it successfully applied by American and European companies. Likewise, the low abstract slogans used in "zero defects" did not create change until it was understood as the high abstract notion of "customer satisfaction". Only then, people began to develop their own solutions that, quite often, differed from traditional "zero defect programs" (Lillrank, 1995).

In the present context, to understand the multi-purpose ideas that constitute best production practices is a necessary step for enabling effective learning. Fortunately, many production theories have already translated a great number of effective production practices into multi-purpose ideas that can be the basis for better knowledge transfer. The principal group of ideas come as a combination of Just-in-Time (JIT) and Total Quality Control (TQC) with other theories such as Visual Management, Total Productive Maintenance, Re-engineering and Value Based Management (Koskela, 1992). According to Koskela (1992) what normally varies is the way the core production theory combines to each different application in practice.

DEMAND DRIVEN VS. SUPPLY DRIVEN KNOWLEDGE

Merely understanding an abstract idea that underlies a particular production practice, and making this knowledge freely available, does not mean that learning is occurring. From a learning perspective, knowledge transfer involves not only transmission (sending or pre-sending to a potential recipient) but, above all, absorption. A successful learning (transfer) process should enable people to become more capable of dealing with unexpected production problems by themselves and, in this way, expand their own knowledge (Davenport & Prusak, 1998). Thus, abstraction of practices must be portrayed in such a way that recipients understand and own the new ideas in their own individual terms.

According to Lillrank (1995), knowledge is more effectively transferred when people demand it (demand driven knowledge) as opposed to situations when knowledge is pushed at them, or simply supplied without being wanted (supply driven knowledge), as illustrated on **Figure 2**:

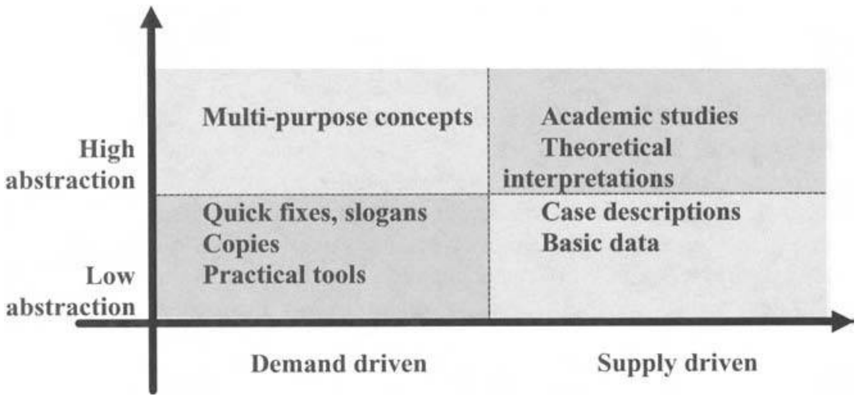


Figure 2 - Model of Transfer Channels (Lillrank, 1995)

In "demands driven channels" people freely request, and more readily absorb, information according to their own wishes and idiosyncrasies. Because of this, new knowledge becomes more meaningful and more likely to be adopted and transformed into innovative solutions. In contrast, in "supply driven channels" people may simply reject new ideas because they do not match their perception relating to their own needs. This lack of awareness of the actual needs and realities of learner recipients often results in reduced ownership and commitment to new information and, as a result, it often fail in generating effective solutions or innovative practices.

Next sections presents the result of an investigation into the effectiveness and dynamics of transferring know-how through abstract principles using both approaches.

RESEARCH STRATEGY

The investigation on knowledge transfer demanded the development of the study in "real world" conditions in order to reflect an actual situation faced by practitioners in everyday life. "Real world" conditions imply little or no control over the events surrounding the observed practices (Robson, 1993). Hence, because of these requirements it was adopted "case study" as the research strategy for this study. The most widely accepted definition of case study is given by Yin (1994:13) who defines it as *"an empirical inquiry that investigates a contemporary phenomenon within its real-life context and where the boundaries between phenomenon and context are not clearly evident"*. This definition is highly pertinent for the present research since the aim here is "testing-out" the validity of a theoretical proposition. In this type of research the kind of control present in a laboratory is not feasible and not even ethically justifiable (Yin, 1994; Remenyi et al., 1998)

The analysis of practices within the case studies took four weeks and used a standard observational protocol. This observational protocol included open-ended interviews, photographs, video-recording and quantitative indicators. The analysis used a process called **pattern matching** where the researcher looked for direct replications of the theoretical propositions (Yin, 1994). In this process, the empirical evidence was considered to be a "literal replication" when observed results matched the theoretical predictions (e.g. a visual control that contributes to facilitate measurements). In contrast, when the case study produced contrasting results but for predictable reasons, it was called a *"theoretical replication"* (e.g. excessive measurement associated with a lack of visual controls). Information obtained through quantitative and qualitative techniques was used to substantiate the pattern matching findings. In addition, boundary searching on the typical values of key quantitative indicator contributed to the assessment of the empirical evidence.

The assessment of practices in the case studies was carried out using twenty-two heuristics relating to four production management principles (reduction of cycle time, reduction of variability, increase of transparency and build of continuous improvement). The principal source of ideas for establishing these heuristics came from the seminal report "*Application of the New Production Philosophy to Construction*", produced by *Lauri Koskela*, from the VTT - Technical Research Centre of Finland.

The study presented here involved the transmission of practices from a Brazilian construction site to an English construction site. Initially, the authors present a diagnostic carried out on the Brazilian construction site that will be the source of knowledge for this study. The subsequent section presents the diagnostic of the

English construction site and the attempts of transferring know-how through abstract principles.

CASE STUDY BRAZIL - DESCRIPTION

The host company in this case study was among the most competitive companies in Rio Grande do Sul, the most southern state of Brazil. In previous years they had received awards from the regional union of contractors due to the quality of their production and commercial innovations. This company could be classified as a medium sized company (100<employees<500) and employed most of its workforce. Its buildings were usually sold before or during the construction, through a system of a hundred payments.

The construction site analysed consisted of a large development of multi-storey housing. The building analysed had twelve storeys with four apartments on each level. The managerial staff on site constituted a foreman, a construction manager and a secretary. The site was located in an area of the city where there were many other new developments that had started after the construction of a large new shopping centre.

The masonry technology used in this scheme was relatively novel in the region and had been used for the first time by this company two years before the researcher's visit. The company had constructed exactly the same type of building many times. Thus, the researcher expected that this company should have had a learning curve effect regarding their new technology. When the research started the concrete structure was ready and the bricklaying activity had reached the half way stage. Water proofing, window fittings and piping were in their initial stage.

The following descriptions represent the most significant practices and characteristics observed in this construction site:

a) *Reduction of Cycle Time*: the bricklaying activity was carried out in parallel with the electrical fittings. This practice reduced future rework and increased the value added by the bricklayer himself. Bricklaying and electrical operations had to be absolutely synchronised and smooth, otherwise the productivity of both trades would have been low and, consequently, their salary;

b) *Reduction of Variability*: this case study showed a fairly standard practice among bricklayers, although there were no written standards available. The workforce had mastered the technology mainly because of the repeatability of design details. Indeed, the bricklayers were very skilful at avoiding unnecessary cuttings of blocks. However, they carried out no activities related to measuring, finding and eliminating root causes of problems. Neither did they got involved in a process for developing standard procedures;

c) *Increase of Transparency*: most workplaces on this site were kept clean and tidy although both electrical and bricklaying activities were carried out simultaneously and with a high level of inter-dependence. This good housekeeping, associated with modularised design solutions, allowed rapid understanding of production status and helped avoid certain errors. The were rare examples of visual controls on this site and this was particularly noticed on the activities involving measurement, and on the achievement of synchronisation between the production of mortar and bricklaying;

d) *Build of Continuous Improvement*: the company's workforce had mastered the new technology and performed their operations in a very efficient way. However the majority of the technological improvements in the production system resulted from actions initiated at the design stage, without any visible contributions from the workforce. However, the partnership between the supplier and the contractor was an essential feature in these improvements.

Figure 3 illustrates that the main focus on this case study was clearly on the approaches aimed at *reducing cycle time* and *increase transparency*.

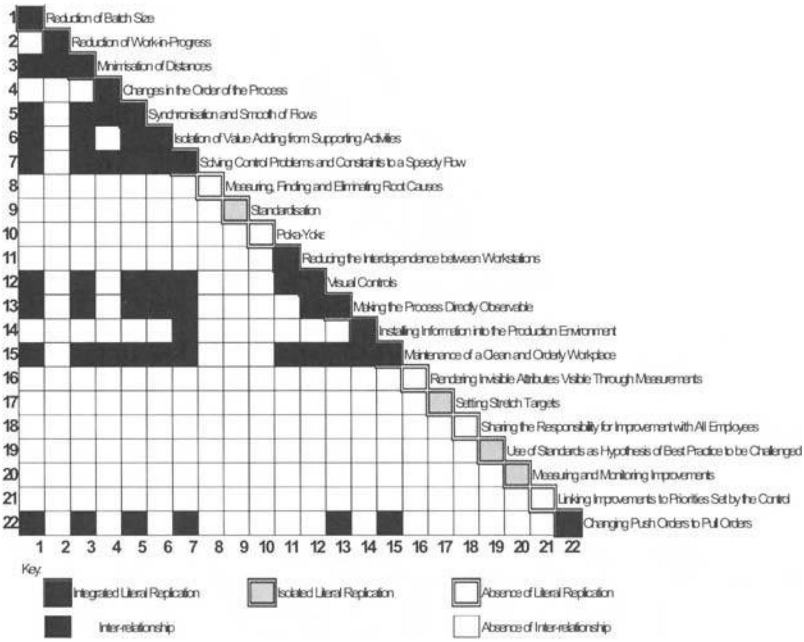


Figure 3 - Integration of Heuristic Implementation Approaches in Case Study B

Despite the lack of workforce participation in continuous improvement activities, it became clear, throughout the data collection, that there was a significant flow of ideas and improvements derived from decisions taken outside the construction site. This flow of ideas and actions came mostly from the middle and top management levels but also involved a growing number of partnerships with suppliers and designers. The brick supplier, for instance, had an essential, and active, role in the development of the new masonry system and its subsequent implementation. Nevertheless, the total reliance on technological and design solutions ignored the potential for even higher gains in performance coming from small improvements on production flows.

CASE STUDY ENGLAND - DESCRIPTION

The host company for this case study was small (20<employees<100), but it had a long tradition in British construction dating back to 1887. With headquarters in Bournemouth, the company also has branches located at Dorchester, Warminster and Warwick. At the time of this research, some of its managers were taking part in a research programme that was used as a vehicle to promote innovative practices in the construction industry. This research programme aimed to investigate *Action*

Learning as a mechanism for driving innovation and cultural change for construction. The ADAPT programme of the European Social Fund, the Innovative Manufacturing Initiative of EPSRC - *Engineering and Physical Sciences Research Council* and the *Chartered Institute of Building College* were the main sponsors of this programme.

The construction site analysed was located in Devizes, southern England, as the target for this investigation. The project comprised a new single storey primary school with a gross floor area of approximately 881 m^2. The construction was founded on part solid and part suspended ground slab with a lightweight steel frame. The external walls used brick cavity construction with aluminium windows and hardwood external doors. The roof was predominantly a steel deck construction covered with aluminium sheeting. The design also specified conventional mechanical and electrical services and a gas fired heating system. The foundation, concrete floor and steel structure were already constructed at the start of the data collection. The roof was in the last stages and the bricklaying subcontractors had already completed the external walls and were halfway to completing the internal walls.

This construction site presented a general lack of most heuristic production approaches investigated in this research, as illustrated on **Figure 4**. The few practices that matched the implementation approaches were not integrated in a coherent system. The roof subcontractor, for instance, had started a long time before the bricklaying activity ("change in the order of the process"). This practice could offer a significant benefit in terms of time compression and reduction of delays due to bad weather. However, there were no continuous improvement activities for capturing the lessons learnt, or attempts to bring both trades to discuss ideas of how to improve the interface between their operations (e.g. "standardisation").

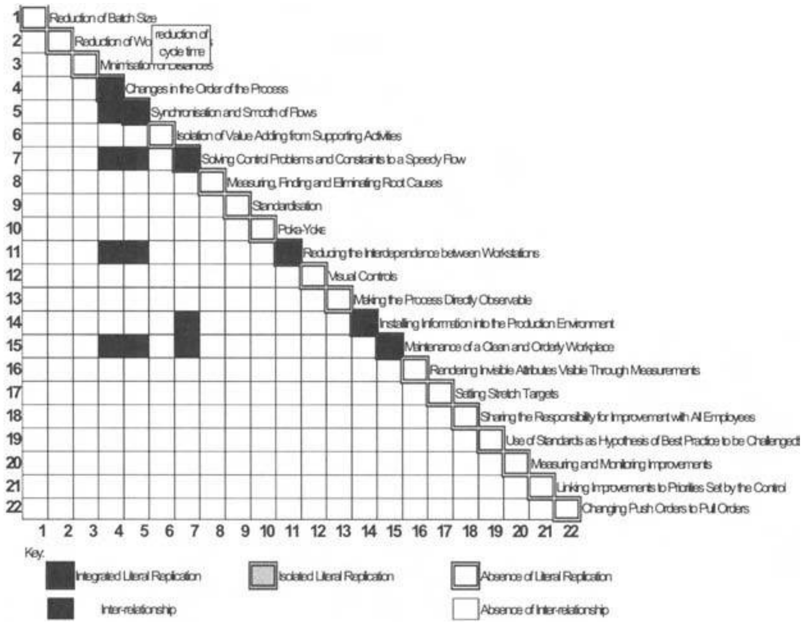


Figure 4 – General Pattern Matching Assessment

The following items summarise the most critical aspects observed in this site regarding the four principles investigated:

a) *Reduction of Cycle Time:* there was an excessive volume for the batch delivered on site and this was attributed to the long distance to suppliers. Also, there was large quantity of small spots of work-in-progress throughout the building, mainly in the interface with the steel structure. Delays in the assembling of scaffolding and frequent design changes resulted in poor synchronisation between processes. There was an excessive distance between workplace and mixer (>100m);

b) *Reduction of Variability:* systematic measurement, identification and elimination of root causes have not been identified. Standards were non-existent and the design was practically the only tool used to communicate the desired product outcome. No poka-yoke devices were identified.

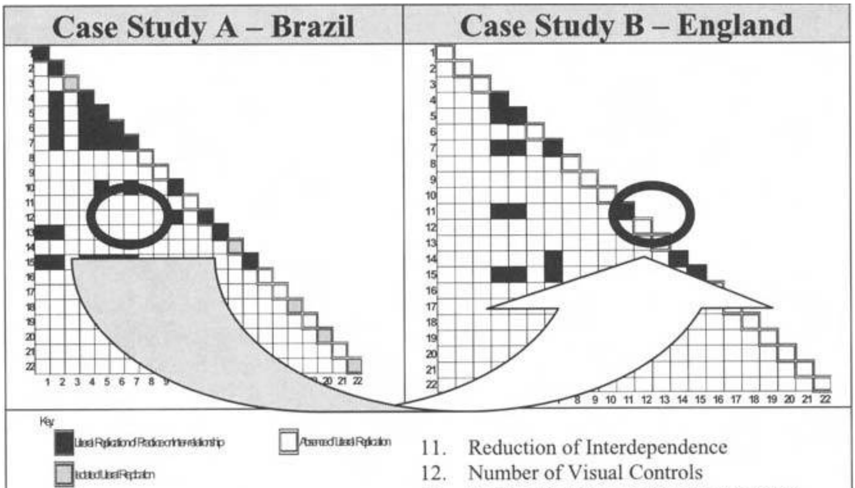
c) *Increase of Transparency:* the bricklaying process was relatively independent of other processes regarding the definition of flows and design interfaces. There were no visual controls or information displays in the workplace or surrounding environment. There was no systematic activity to maintain a clean and orderly workplace, though the site was in an acceptable condition;

d) *Build of Continuous Improvement:* there was no systematic problem solving activities. However, informal problem solving activities took place when it involved design and specification problems. The site manager was the only person responsible for devising improvements on the site. Yet, there were no standards available to be used as hypotheses of best practice and the only control verified was the schedule control and even that was not used to feedback improvement activities. None of the bricklayers had previous exchange of ideas or information with the upstream operations (e.g. roof, design).

TRANSFERING KNOW-HOW: THE CASE OF BATCH SIZE PRACTICES

Assessing the Potential for Know-how transfer

The complete description of the learning experience that occurred between Case Studies Brazil and England is fully described elsewhere (Santos, 1999). For the purposes of this paper the authors have chosen "reduction of batch size" as theme to illustrate the identification of knowledge needs using abstract principles. Reduction of batch size simply means to reduce the size of production or transportation volumes within the construction process in order to speed up the delivery of products to the internal or external client (Santos, 1999). **Figure 5** shows that there was great potential for transferring this and other practices from "Case Study Brazil" to "Case Study England".



1. Reduction of Batch Size
2. Reduction of Work-in-Progress
3. Minimisation of Distances
4. Change in the order of the process
5. Synchronisation and Smooth of Flows
6. Isolation of Value Add from Support Activities
7. Solving Control and Constraint Problems
8. Measuring, Finding and Eliminating Problems
9. Standardisation
10. Poka-Yoke
11. Reduction of Interdependence
12. Number of Visual Controls
13. Making the Process Directly Observed
14. Installing Information into the Workplace
15. Maintenance of Clean and Orderly Workplace
16. Rendering Invisible Attributes into Visible
17. Setting Stretch Targets
18. Sharing the Responsibility for Improvements
19. Using Standards to Challenge Practices
20. Measuring and Monitoring Improvements
21. Linking Improvements to Control
22. Change Push Orders to Pull Orders

Figure 5 – Illustration on the Possibilities of Know-How Transfer

It is worth reminding that the central focus of observations of this heuristic during the diagnostic of each case study was on the amount of material arriving in each delivery to bricklaying, the amount of work-in-progress, the bricks/blocks storage volumes and the relationship of these variables with production rates. Observations started in the exploratory visit with photographs and video recording of the process status in terms of workflow, layout and storage volumes. Subsequently, during two weeks the researcher documented the position of workstations and measured productivity and storage turnover.

The relationship between the productivity and the storage turnover helped in understanding how lean and synchronous the flow of bricklaying was. Analysis of documents and archival records directly concerning bricklaying helped to check if the frequency and volume of deliveries were consistent throughout time. The work-sampling technique (or time-lapse video recording) showed the effect of large batches on the generation of non-value adding activities.

Comparing Batch Sizing Practices

The observations have shown the widespread use of large batch sizes in the bricklaying activity in both case studies. "Delivery batches" were not consistent with the workstation consumption rate. Indeed, **Table 1** shows the severe discrepancy between the 'average storage' on site and the 'productivity rates'. However, Case Study "Brazil" presented the best performance in this respect with values of flow efficiency (productivity/average storage) three times higher than Case Study "England".

Table 1 - Performance of Case Studies

INDICATOR	CASE STUDY *BRAZIL*	*ENGLAND*
Number of Bricklayers	4	2
Gang Composition (Bricklayer:Labourer)	2:1	2:1
Productivity (A) (m^3/hour/bricklayer)	0.19	0.16
Maximum Storage of Bricks/Blocks (m^3/hour/brickl)	6.20	10.10
Minimum Storage of Bricks/Blocks (m^3/hour/brickl)	1.00	5.00
Average Storage of Bricks/Blocks (B) (m^3/hour/brickl)	2.62	7.20
Flow Efficiency (A/B)	0.07	0.02
Number of Days Observed	10	10

The great lack of synchronisation between the workstation's rate of consumption and the flow of material in Case Study "England" resulted in the obstruction of pathways and increase of non-value adding activities. Furthermore, the researchers witnessed on various occasions the delivery of various truckloads in a short amount of time and then, longer periods without a delivery. These variations created difficulties in the pathways on site and reduced the transparency for stock control. The lack of detailed workflow plan, clearly defining the expected consumption of material and the actual direction of flows, was a major factor increasing still further the impact of large delivery batches.

In general, the observations revealed that equipment, packing methods and containers used in Case Study "England" had not being developed with the purpose of enabling effective small batches. Indeed, most of the equipment observed had been developed using the paradigm of mass production of large batches. Discussions with the site managers and workforce revealed it was they understood that the delivery of large batches, and maintenance of large storage, was necessary in order to tackle the high level of variability on site and on the supply chain. They also believed a reduction in 'delivery batches' would increase the costs of transportation. When asked about the possibility of developing alternative transporting and packing systems to enable the reduction of "delivery batches" they expressed their frustration for lacking the power and means to influence the supply chain in this way.

The open-ended interview revealed that the site manager and bricklayers in this site had no clear understanding of the implications of reducing the size of 'transfer batches'. Their normal policy was to put as many bricklayers, and as much equipment and material on site, in order to carry out constructing as many brick/blockwalls as possible. The financial constraints of the project seemed to be the main driving force in defining the size of "transfer batches" (batch of brickwals ready to receive next process). Furthermore, large buffer in schedule resulted in great amount of waiting of finished brickwalls. From the conversations with managers the researcher concluded that there was no intention of reducing "transfer batches" to enable early start of downstream processes since they saw this as an increase in production complexity.

In Case Study Brazil the supply of bricks and blocks was much closer to the actual needs of the workstation than Case Study England ("flow efficiency = 0.07"). Moreover, the transportation system allowed the movement of smaller amounts of bricks. The clear benefits of smaller batch sizes were better visibility of process flows and reduction in transportation distances.

It became clear from the observations and discussions with managers in this site that this approach can drive improvements and innovations in design and production. Solutions should be developed in order to enable the production and transfer to the next process of one single batch unit at a time, even if it is not required in the present demand levels. For instance, interdependencies between batch units need to be reduced at the design stage in order to allow the unrestricted work of downstream processes. The site manager should strive to bring on the next process as soon as any bricklaying batch unit was ready. Hence, large buffers in schedules, process variability, design constraints and the lack of adequate workflow planning should be tackled during the implementation of such an approach.

Nevertheless, analysis of the archival records showed that the practice of this case was not consistent throughout time. During the ten-day's observation period the researcher observed a large variation between the maximum and minimum volumes of storage (from *1.00 to 6.20* m^3). Managers and workers on the Case Study "Brazil" shared the opinion that the reason for such a variation of storage on site was the high level of trust on the reliability of the blick's supplier. The commitment of the project manager to partnerships translated into a commitment to maintain the same supplier throughout the entire project. The resulting trust allowed the site manager to order loads of bricks at the last possible minute. Usually, only when stock levels reached the equivalent of the needs of two days of work, would they communicate their orders to the supplier. Each supplied truckload contained enough material enough for one week of work. However, the large volume of blocks in each truck demanded the relocation of bricklaying labourers to support the unloading activity.

Discussing Current Practices with the Workforce

A meeting was organised in order to present the diagnostic to the workforce, improve the diagnostic itself and discuss alternative practices. The meeting took form of a brainstorming session and had the participation of the site manager and the two bricklayers and labourer involved in the process under analysis. The participants were told about how a brainstorming session works since that was the first time they had a meeting of this kind.

Before starting the brainstorming session, they received a detailed account of all information collected during the two observational weeks, including photographs, work sampling graphics, filming, quantitative indicators and flow diagrams. The presentation of quantitative data included comparisons with benchmark references. Most importantly, it included comparisons between some of the poorest practices on their site and better practices identified elsewhere in the globe. The emphasis here was on the theoretical and practical differences and their implications in terms of process performance. This presentation included a description of how the heuristics, such as the "reduction of batch sizes", work in other companies and what the benefits are for bricklayers and site managers. It was here that empirical evidence collected on Case Study "Brazil" helped them to understand the meaning and implications of smaller batch sizes.

At the beginning of the brainstorming session, participants were shy to expose their opinions, but with the stimuli of real case material, they gradually began to participate actively. The entire brainstorming session lasted for about two hours and only finished when the suggestions became scarce. At the end of the meeting, the researcher asked the participants to select what they thought to be the most important ideas that came up during the brainstorming session. Each participant could choose five ideas and the vote was secret. Secrecy was important since the labourer's and bricklayers might otherwise be afraid of contradicting the opinions of the site manager.

As shows **Table 2,** the distribution of votes revealed that the workers were more concerned with those solutions that reduce cycle time.

Table 2 - Priorities of Improvement Following Brainstorming

PROBLEM	Votes	Cycle time reduction	Reduction of Variability	Increase of Transparency	Continuous Improvement
DESIGN					
Produce design according to module	4	XXX	XXX		
Planning the work in packages*	4	XXX		XXX	
Improve communication with designer	3		XXX	XXX	XXX
FORKLIFT					
Hiring a mechanical fork lift	3	XXX			
Improving the gears of the manual lift	1	XXX			XXX
Developing diagonal lift	1	XXX			
Reducing the size of pallets	1	XXX			XXX
Installing loading bays on scaffolding	1	XXX	XXX		
WORKING CONDITIONS					
Improving site conditions (ex: ladders)	2		XXX		XXX
Only 25 kg cement packs	1	XXX	XXX		
Reducing the weight of blocks	1	XXX			
Changing wheels of wheelbarrow	1	XXX			

*The aim here was the reduction of "transfer batches"

Note that in this rank of problems the workforce have included two topics related to the reduction of batch size. Conversations after the meeting confirmed that they clearly understood the benefits and requirements for reducing batch size on site. They realise, for example, that smaller batch sizes would require other complementary practices such as visual controls, partnership with suppliers and continuous revision of layout plans.

CONCLUSION

The model of "know-how" transfer proposed by Lilrank (1995) seems to be useful in practice. In other words, the abstraction of practices appears to be an effective instrument for identifying the needs for knowledge transfer across organisations and countries. It enables more creativity during a benchmarking process, for instance, since the same core ideas can lead to different alternative solutions. High abstract interpretations increase the flexibility to adapt the findings from one environment to another and that is more evident within international knowledge transfer.

The communication of abstract findings to the workforce in the case study only worked because they had the knowledge presented at a level of abstraction which suited them and because they were motivated to accept that knowledge. They only manifested clear understanding of the abstract principles when the researcher was able to show real examples, preferably referring to similar processes, in similar situations to the ones they were engaged in practice. Finally, the case study showed that better preparation of the staff with respect to the abstract production management principles contributes to speeding up the transfer process.

ACKNOWLEDGEMENTS

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IMPLEMENTING ISO 14000 ENVIRONMENTAL MANAGEMENT SYSTEM IN CONSTRUCTION PROJECT MANAGEMENT COMPANIES IN SINGAPORE: A QUALITATIVE STUDY

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ABSTRACT

The adverse environmental impacts of construction activity are now well recognised. Much work has been undertaken on how construction projects can be managed to reduce these impacts. The ISO 14000 environmental management standards (EMS) have been found to be beneficial in many field of activity. In addition to helping firms to limit the effect of their activities on the environment, it also offers tangible commercial advantages. However, the EMS is new in Singapore's construction industry.

This paper reports on a research study undertaken to examine the perceptions of professionals involved in construction project management in Singapore towards

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improved environmental performance, and to assess the extent of awareness of ISO 14000 within the industry. The study was based on a series of interviews with construction senior practitioners, environmental consultants, and administrators. It is suggested that more should be done to encourage the adoption of ISO 14000 certification in the industry by undertaking research to provide credible evidence of its benefits.

Keywords: environmental management, ISO 14000, benefits, costs, client's role

INTRODUCTION: ISO 14000

An environmental management system (EMS) includes the organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining a company's environmental policy (ISO, 1996). The ISO 14000 series of EMS standards provides organisations the framework for managing the environmental impacts of their operations (Cascio, 1996; Puri, 1996).

Highlighted benefits from ISO 14000 EMS implementation include (Kuhre, 1995; Tibor and Feldman, 1997; Ritchie and Hayes, 1998): reduced operating costs; increased access to markets; demonstrated compliance with regulations; improved environmental performance; improved customer trust and satisfaction; enhanced corporate image and credibility; employee involvement and education; and potential impact on world trade to allow competition on an equal basis.

Drawbacks of ISO 14000 adoption include (Tan *et al.*, 1998): short-term costs in employing environmental consultants, setting up management structures, and organising training for employees. There can be disruptions to work flow, delays and increased costs. The need for continuous improvement can be onerous; and the organisation's subcontractors and suppliers must improve their environmental performance if it is to derive results from its EMS.

The first Singapore construction enterprise to be ISO 14001 certified (in 1998) was Neo Corporation Pte Ltd. Dragages et Travaux Publics followed in April 1999. In October 1998, the then Construction Industry Development Board (CIDB) ISO 14000 Certification Scheme (*Construction Focus*, 1998) was introduced, and by the end of 2000, 10 construction organisations had been certified under this scheme. Tan (1997) and Tan *et al.* (1999) found that many construction firms were aware of the ISO 14000 EMS but would only adopt them if it became mandatory. Kienta Engineering Construction Pte Ltd derives cost savings by adopting the following measures after being ISO 14001 certified: use of materials which can be recycled, such as metal formwork; use of a thinner layer of mortar for plastering after improving the quality of structural works; use of pre-packed mortar for plastering; and using rainwater instead of potable water at the washing bay.

In 2001, the Building and Construction Authority (BCA) (which the CIDB became in April 1999) announced that from July 2003, construction firms must be certified to ISO 14001 before they can register to undertake public sector projects. Firms in Singapore are now being encouraged to seek certification to integrated management systems incorporating quality, the environment, health and safety (Griffiths, 2000; *Frameworks*, 1999; Dhaliwal, 2000).

RESEARCH OBJECTIVES

The research study sought to:

- determine the attitudes, values and beliefs of professionals involved in construction project management in Singapore towards improved environmental performance

- assess the extent of awareness of ISO 14000 within the industry

- identify how organisations involved in construction project management can conform to the requirements of ISO 14000

- offer recommendations on measures, which can be instituted to make construction firms more committed to the protection of the environment, and propose how these can be monitored.

A review of literature informed the preparation of questions for a mailed questionnaire survey and a series of interviews. Among those interviewed were: the Executive Director of the Singapore Environment Council; the senior management of three environmental management consultancies; senior officers of the then Construction Industry Development Board (CIDB); the Productivity and Standards Board (PSB); and senior officers of the Ministry of the Environment.

THE INTERVIEWS

Potential for take-up of ISO 14000

The interviewees highlighted the following environmental consequences of construction activity: soil erosion and discharge of silt; breeding of mosquitoes; high levels of wastage of materials, especially of cement and reinforcement bars;

damage of completed work by subsequent gangs owing to poor scheduling, contributing to wastage; emission of dust; and emission of noise.

> One interviewee commented on the practices of the construction industry in Singapore:
> Every site you see, there is tremendous wastage. So there is a lot to improve, especially in scheduling.

The following means by which Singapore's general environmental performance and that of the construction industry can be improved were highlighted: (i) by the use of new technology; (ii) by increasing the number and level of training courses; (iii) by offering more financial incentives and soft loans for local enterprises; (iv) by giving more tax allowances for good environmental performance; (v) by promoting the uptake of the ISO 14000 standards series; (vi) by assisting enterprises to acquire vital resources such as land, for environment-related operations such as recycling. It was also noted that often, the regulatory approach is not effective due to the low quantum of specified fines for non-compliance with environmental regulations.

Problems of take-up of ISO 14000 certification by construction enterprises which the interviewees identified include: (i) clients and designers do not advocate environmental protection and the adoption of environmentally-friendly methods; (ii) certification to the standard is not mandatory; and (iii) the firms cannot see many cost savings from environmentally responsible behaviour. The cost focus of construction firms was particularly highlighted. One interviewee said:

> Unless it affects the bottom line, if they can get away with it, they'll get away with it; even the big boys.

Promotion of ISO 14000

At the time of the interviews, some 65-70 companies in Singapore had attained ISO 14001 certification. Only two of these firms were from construction: one contractor and one ready-mixed concrete producer and supplier. It was observed that Singapore's numbers compared favourably in relative terms with that of the US, where there were only 190 ISO 14000 certified firms.

The PSB works closely with the Ministry of the Environment to promote ISO 14000 certification. The Ministry helped to form the *Steering Committee for ISO 14000* through the Singapore Confederation of Industries. The committee seeks to help small and medium-sized companies to be ISO 14001 certified. The PSB publishes a twice-yearly supplement in the main English newspaper on the standard (*The Straits Times*, 1998, 1999). Financial assistance schemes to encourage companies to adopt environment-friendly policies are administered by the PSB.

These include loans and grants to: buy new equipment; defray training costs; engage consultants. The authorities are aware that they cannot be sure whether these schemes are sufficient. They aim to target these only at “viable companies”. Some of the interviewees mentioned that there appeared to be some inappropriateness with the PSB’s being both a regulator and certifier with respect to the ISO 14000 series standards.

Training for EMS is undertaken by the Regional Institute for Environmental Technology (RIET), Nanyang Polytechnic and some environmental consultants. At the time of the interviews, the then CIDB was in the process of preparing to put the environment among the items at the top of its agenda, and to launch the ISO 14001 certification scheme. Before then, *the environment* had not been given much attention because it was not seen as “a national issue, like foreign workers”. The impetus for the then CIDB to become involved in ISO 14000 series certification came from continuing requests from ISO 9000 contractors which it had certified, which wished to proceed onto ISO 14000. At the time of the interview, some 200 construction enterprises had obtained ISO 9000 through the CIDB.

Costs and Benefits of ISO 14000

The interviewees noted that benefits of the introduction of EMS in construction organisations would be wide. They would accrue to the firms themselves, the people living near the sites, the general public, and the government (the controlling authorities).

There was a perception among the interviewees that the construction industry needs much encouragement and assistance to become environmentally aware. That ISO 9000 has become common within the industry was considered a good thing because it would show enterprises the merits and implications of a management system. ISO 14000 was perceived to bring benefits, in particular, the ability to identify wastage. One interviewee stated firmly that: “ISO 14000 leads positively to good environmental performance”. However, possible costs were also mentioned. One interviewee observed:

> There is a cost involved if you want a management system. You need people dedicated to it. You need training for managers right down to workers. There is a lot of cynicism among people but in the end, it helps.

The interviewees stressed that certification is not an end in itself. There should be periodic follow-up to check compliance and make arrangements for continuous improvement. Regular inspections are proposed for ISO 14000. Meeting the set targets and continuously improving upon them is a vital challenge. Experience in

Singapore among "line managers" is that in the first few years, targets are easy to meet but this will be harder in future. One interviewee noted:

> The CEO is happy to sign but his people must work hard to achieve the targets. The big issue is how can a system of continuous improvement be sustained over time.

Some of the problems of ISO 9000 implementation which Singapore construction firms have experienced may plague that of ISO 14000 (ISO 9000 certification is mandatory for large construction and consultancy firms which wish to undertake public-sector projects). One interviewee noted:

> Many are going in [for ISO 9000 certification] because of the requirements but not believing in it. But after a cycle or two, they begin to see the benefits. We always encourage them to fine-tune it. There's plenty of paper work so we get them to review, merge, reduce.

Another interviewee remarked that construction companies (and many in other sectors) which have sought ISO 9000 certification are motivated by "the paper". He added:

> They are not driven by continual improvement, empowerment, and that sort of thing, but so that they can have a certificate they can pin to the wall.

Difficulties in implementation

One of the main barriers to the implementation of ISO 14000 which was identified by the interviewees is the lack of motivation. A key issue is the first step where the firm's top management adopts environmental management within the company. The top-down approach was considered to be important to ISO 14000 implementation.

One interviewee pointed out that ISO 14000 does not set actual standards or levels. Instead, it establishes management processes. Companies usually aim too high and then have to cut down on objectives and targets. However, continuing improvement is a good feature of ISO 14000 as it assists firms to upgrade their operations over time.

The interviewees noted that the Ministry of the Environment and other regulating authorities with tasks relating to the environment expect that organisations which have attained ISO 14001 certification will pose less problems than those which have not done so. The Ministry indicated that it will still monitor and control the operations of companies which are ISO 14001 certified, although it might give some concessions to certified firms.

The construction sector is unusual in relying heavily on a large number of sub-contractors. One interviewee noted that the subcontractors must comply with all aspects of the EMS standard if the aim of protecting the environment is to be achieved. However, that interviewee noted that there is no requirement in the ISO 14000 series for compliance by suppliers as this would be unreasonable. Encouragement would have to be given to the sub-contractors to make them more environmentally friendly especially in the utilisation of resources.

ISO 14000: Mandatory or voluntary?

Like some authors (see, for example, Tan, 1997), many of the interviewees noted that the construction enterprises in Singapore are “driven by legislation”. The question of whether ISO 140000 (like ISO 9000) certification should be made mandatory was posed during the interviews. Different views were expressed. One interviewee noted:

> Unless it is a procurement requirement like the 9000, I don’t think you will get the response. If it is voluntary, I don’t see too many. But some are interested.

The Ministry of the Environment and the CIDB preferred that ISO 14001 certification remain voluntary. The interviewees generally believed that it was best to leave the take-up of ISO 14000 certification to market forces. They hoped that the cost savings from the implementation of EMS would offer an incentive for such certification. They believed that mandatory requirements or coercion (as with ISO 9000) would not engender real motivation among the organisations to be environmentally friendly. The respondents thought that construction firms of all types and their owners and top managers, should truly believe in ISO 14000 certification and implementation, rather than just adopting it to comply with regulations. Their commitment to further improve upon their environmental performance in the latter case would be low. In this respect, the respondents noted that ISO 14001 certification of companies is more often driven by customers and suppliers.

The success of ISO 14000 is determined by the market mechanism. Companies will embrace ISO 14000 only when they can be sure that implementation of the EMS prescribed in the standard will improve their business performance in commercial (profit) terms. In this connection, benchmarking the benefits derived by organisations which have implemented ISO 14000 against those of the firms which are not certified will be a useful exercise.

However, one interviewee noted that the environmental commitment and performance of the construction industry in Singapore is poor. This is due to the need for companies to be highly competitive and meet the needs of the market place. Thus, in the absence of mandatory requirements, it is unlikely that such firms will change.

Motivation needs to come from the top either through the managing director, board or through the client. The introduction of mandatory legislation would also be effective provided it is appropriately enforced. Another feature of Singapore construction firms which militates against their environmental performance is that most employees are engaged on a temporary basis and may generally comprise a wide range of nationalities and cultures.

Requirements of ISO 14000: Training

Companies seeking ISO 14001 certification must train their personnel to prepare them for their responsibilities under the EMS. Some companies send all levels of their staff to training courses run by environmental consultancy firms. Given the high proportion of foreign personnel in several sectors of the Singapore economy, many of the courses are run in different languages for immigrant workers. In construction, this will be essential, as some 85% of site construction workers are foreign. The then CIDB indicated that it did not intend to run training and awareness sessions in relation to its ISO 14000 certification scheme. It believed that consultants will be best able do this.

The interviewees pointed out that while training courses (to raise the awareness of workers) are useful, and are, indeed, required by the ISO 14000 standards, changes in attitudes is a long process and the 'doing' is more effective especially when top management set the example. One of them highlighted the problems the industry in Singapore will face in trying to meet the ISO 14000 requirement for training: (i) very high turnover of foreign workers; (ii) communications problems; and (iii) high cost of training. It was pointed out that EMS implementation will result in particularly strong pressure on personnel costs.

Future Possibilities

The interviewees agreed that construction operations will follow a general trend towards greater environmental compliance in future. They noted that there will probably be more emphasis on dry rather than wet trades on site. Greater application of prefabrication and the use of precast concrete and, perhaps, more modularisation, may take place. Moving much of the work of the construction industry from the site to the factory would reduce wastage and avoid various forms of pollution which result from poor management and carelessness on site. The realisation of such practices would offer several benefits in addition to the environmental ones: it would reduce the industry's requirement for workers; enhance quality control; and eliminate problems with inclement weather. The site will become an assembly point rather than a construction yard.

The client's vital role in promoting the adoption of EMS by construction project management enterprises was stressed by the interviewees. The environmental commitment and requirements of the multinational companies, especially those in the petrochemical business, was cited as an example. It was observed that these corporations are very sensitive about their public image. One interviewee highlighted Shell's stringent enforcement of its integrated quality, safety and environmental programme, and its sanctions against infringements, as well as actions following mishaps. He ended his remarks on this point by saying:

> There should be no problem for construction companies to implement 14000 because they have the quality management system in place, with the 9000. It's a question of commitment, and therefore, education. Clients' commitment is important.

Another interviewee noted:

> We should target at the upstream. If the clients are aware of how it would help them to save money, etc, it will be transmitted down. It's no use the contractor having ISO 14000 if the client is not concerned.

The then CIDB believed that the design stage is an important legitimate target. It believed that to be effective, environmental considerations should start at the design stage, with the selection of materials, and so on. Among the benefits will be a reduction in pollution and wastage.

Other interviewees stressed the importance of management during the entire construction project. One of them observed:

> The critical problem is effective management. If they can overcome that, then the environmental system will be possible. Otherwise, ISO 14000 will be a big problem for them.

CONCLUSION

What motivates construction firms in Singapore to take up ISO 14000? An interviewee suggested that the probable reasons for this is that the firms want to minimise costs which may be achieved by recycling waste, reducing energy, and reusing materials such as formwork. ISO 14000 offers benefits to construction firms. However, making it a mandatory requirement will not necessary engender a culture of environmental responsibility and commitment to improved performance. Efforts should be made to clearly demonstrate the benefits of such corporate policies through focused research. Clients' action is also key.

ACKNOWLEDGEMENT

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A Quest for Quality Improvement in Hong Kong

By Albert PC Chan[1] and Daniel WM Chan[2]

ABSTRACT

Quality and quality improvement have been receiving increasing attention worldwide. The finished product in any industry should be manufactured to a certain standard, one that meets customer satisfaction and provides value for money. The need for achieving quality of the finished product in the construction industry is of equal importance to any other industry. The high cost of building makes it necessary to ensure quality of the finished product. A funded research is currently undertaken in Hong Kong to identify factors that showed a strong correlation to good quality and establish how these factors affect the quality outcome of a construction project. The ultimate goal is to provide clients; project managers, designers and contractors with information that can help them become more efficient with their limited resources, and, as a result, achieve better quality outcomes. The aim of this paper is to provide an interim report on this on-going research project. The development of quality systems in Hong Kong will be reviewed. A research framework outlining the research approach, methodology, and the analytical tools for this project will be discussed.

Keywords: Quality improvement, construction industry, Hong Kong.

INTRODUCTION

Since the early 90's, most industries are subject to unprecedented changes in the level of competition, which has greatly intensified worldwide (Sohal and Davis, 1994). With geographical barriers falling, organizations are looking beyond the firm next door to far-flung competitors in an ever-widening market (Sohal, 1998). This globalisation imposes a era to management. This approach asks every employee to continuously improve everything that he or she does in the interest of the customers (Gunasekaran et al., 1998). This 'continuous quality improvement'

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has been identified as one of the key elements of total quality management (Love et al., 1998; Chan and Yu, 2000). Successful applications of this concept to improve quality have been reported in manufacturing and service industries (Lee, 1998; Love et al., 1998; Tam and Hui, 1996; Chan and Chan, 1994; Chan et al., 1997).

However, unlike other industries, the construction industry is characterized by activities that are discontinuous, dispersed, diverse and distinct (Tay, 1994). Quality management in the construction setting is therefore more difficult to implement and a sustainable improvement in quality is difficult to achieve (Low and Tan, 1996; Chan, 1994; Chan, 1996; Chan and Tam, 2000; Chan et al., 1997; Chan and Fan, 1999). There is a need to identify factors that showed a strong correlation to good quality and establish how these factors affect the quality outcome of a construction project.

The aim of this paper is to provide an interim report on an on-going research of quality improvement. The development of quality systems in Hong Kong will be reviewed. A research framework outlining the research approach, methodology, and the analytical tools for this project will be discussed.

DEVELOPMENT OF QUALITY SYSTEMS IN HONG KONG

Due to the scarcity of land and very rapid increases in population, the Hong Kong government was more concerned about quantity than quality of housing in the 60's and 70's. This resulted in poor quality public housing and concomitant high maintenance and remedial costs incurred in the last decade. In pace with the economic progress and the worldwide quality awareness, the aspirations of Hong Kong people have increased and the whole of society has become more quality aware. In recent years, the Housing Authority introduced the Performance Assessment Scoring System (PASS) and ISO 9000 certification requirement in order to overcome its poor quality image. Along with the government's "Quality Awareness Campaign", the Housing Authority, and the Works Bureau took initiatives to strive for an improvement in the quality standards of its contractors (Ahmed et al, 1998). The Housing Authority required that before 31 March 1993, all construction contractors must be ISO 9000 certified otherwise they would be deprived the right to tender for Housing Authority's projects. The Works Bureau of the Hong Kong Government made it a mandatory requirement that all architectural and associated consultants obtain ISO 9000 certification as a condition for inclusion in the consultant lists (Works Bureau, 1997). As the Hong Kong construction industry is dominated by projects sponsored by the government, contractors and consultants have to adopt ISO 9000 series of standards within the time frame prescribed by the government. The government's initiatives to improve quality management are shown in Table 1.

RESEARCH MODEL

Factors affecting project quality

Various attempts have been made by different researchers to determine critical success factors in construction (Beale and Freeman, 1991; Ashley et al.; Pinto and Slevin, 1987). The literature abounds with lists of variables supposedly influencing the quality of a building project. There are some variables common to more than one list, but there is certainly no general agreement on the variables. Review of this previous research reveals some common threads of variables as affecting the quality of a building project. The generally perceived factors that influence quality performance can be grouped under the headings of client, project, project environment, project team leaders, project procedures, and project management actions (Chan and Tam, 2000; Chan, 1996).

Table 1 Government's initiatives to improve quality management

Source: Adopted from Ahed et al, (1998).

Initiatives	**Enforcing Bodies**	**Year of Implement-Ation**
Performance Assessment Scoring System (PASS) scheme, which aimed at linking tendering opportunities with contractor's quality performance and capabilities	Housing Authority	1991
Maintenance Assessment Scoring System (MASS) scheme for maintenance works	Housing Authority	1991
All building contractors required to achieving ISO 9000 registration	Housing Authority	1993
All engineering, architectural and associated consultants required to ISO 9000	Works Bureau	1996
All List I & List II, Group C contractors required to be certified to ISO 9000	Works Bureau	1996
All specialist contractors for land piling -Group II required to obtaining ISO 9000 certification	Works Bureau	1998

Measures of quality outcomes

In an attempt to improve the quality management of public housing construction in Hong Kong, the Hong Kong Housing Authority (HA) has implemented the performance assessment scoring system (PASS) as a mechanism for evaluating the effectiveness of a contractor's ability to deliver projects to specified standards. The principal aim of the PASS score is to measure performance output directly against standards and to provide a fair means of comparing the performance of individual contractors (Tam et al., 2000). At a particular sampling location, the construction work that is to be assessed is judged in terms of its compliance with pre-defined standards. PASS is divided into three types of measurement – output, input and maintenance assessments. The input assessment mainly deals with the management capability, organization and communication issues. The output assessment is to assess the quality of the final output of building works. The maintenance assessment is carried out during the maintenance period, which is aimed at checking how the building functions after occupation. The combined input and output assessments will give a composite score, which will be used for consideration of tender opportunities. The maintenance assessment is used as a supplementary tool for decisions to penalize contractors. These measures will be reviewed and adopted as the means of assessing quality outcomes for this study.

The HA took past performance into account in the award of a tender and introduced a new Preferential Tender Award System in 1999. Under the new system, a Preferential Tender Score is calculated on the basis of a Price Score with weighting of 80% and PASS Score with weighting of 20%, (HKHA, 2000). The tender with the highest score will be recommended as the successful tender.

PASS System

PASS was adopted in 1990 and has been used to measure the performance of building contractors on new works since 1991. PASS has the following objectives and functions (HKHD, 1996): -

- to provide a systematic method of inspection in assessing the contractors' performance in both quality of works and construction safety;
- to facilitate the management of the contractor lists (Figure 1) and
- to encourage contractors to improve performance.

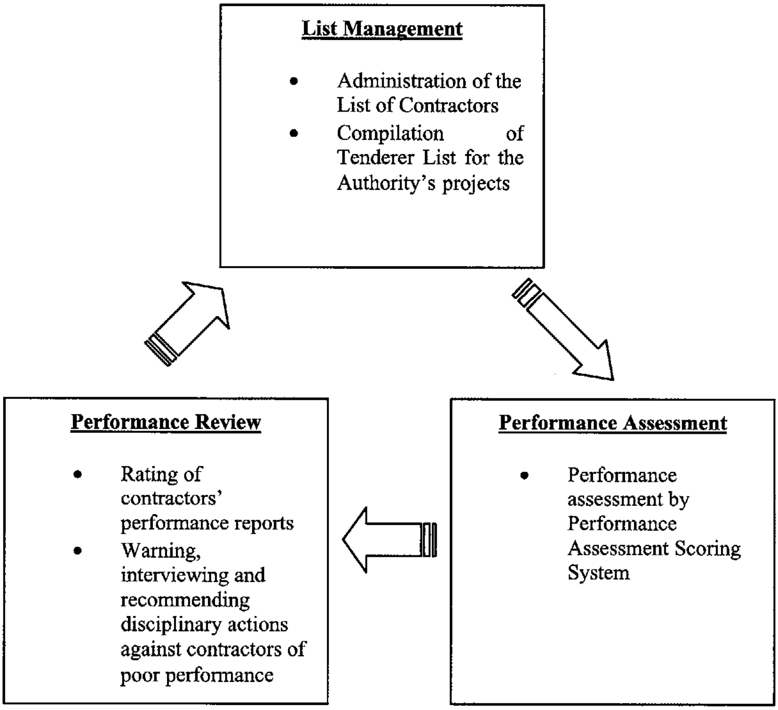

Figure 1 Mechanism of managing the contractor lists by the HA (HKHA, 1997)

Contractor's performance is measured by a set of assessors' rating. The assessors are made up of the HA's in-house project team. PASS is used to identify substandard works for remedy and evaluate contractors' performance for reward purpose rather than to provide information for preparing development plan to prevent non-conforming works. Therefore, this performance measure is detection oriented rather than prevention oriented (Lai, 1999).

PASS has been under constant review to provide an objective means to assess quality standards of end products and safety standards during construction for improving building contractors' performance (HKHA, 1997). The existing system, PASS (1997 edition), is divided into three types of measurement: 'input', 'output' and 'maintenance' assessment. The Output Assessment, which measures the standard of works produced monthly, was first introduced in the assessment system at the beginning of 1991. Since the PASS is administered by the HKHA for all its new work projects, it is an effective means to measure the quality performance of housing projects, which are the targeted samples of this study.

RESEARCH FRAMEWORK

Research Aim and Objectives

The aim of this project is to identify factors that showed a strong correlation to good quality and establish how these factors affect the quality outcome of a construction project. The ultimate goal is to provide clients, project managers, designers, and contractors with information that can help them become more efficient with their limited resources, and, as a result, achieve better quality outcomes. The specific objectives of the study are to:

I. Identify the underlying factors affecting the quality of building projects in Hong Kong.

II. Identify the principal measures of building quality.

III. Conduct an empirical study to identify factors that show a strong correlation to quality outcomes.

IV. Develop a conceptual model that shows the causal relationship between the critical success factors (CSF) and the quality outcomes.

Research Hypotheses

The study contains one central hypothesis:

Quality performance is a function of the characteristics of the client, the project, the project team leaders, project procedures, managerial actions and project environment.

A number of sub-hypotheses are derived from this central hypothesis:

I. Client characteristic is a critical success factor affecting quality performance.

II. Project characteristic will determine the quality performance.

III. Project environment factor will determine the quality performance of a housing project.

IV. Project team leaders' characteristics will affect the quality performance of a housing project.

V. Project procedures will have a significant impact on the quality performance of a housing project.

VI. Project management actions are crucial to the quality performance of a housing project.

Research Methodology

Sekaran's (1992) research process model will be applied in this research. This model provides a helpful process for basic and applied research. This model is to convert the vague ideas from research team into testable hypotheses that are designed specifically for the research questions (Walker, 1997).

The specific methodology of this research will follow the concept of Walker's model, which will be based on literature review, questionnaire, interviews and case studies (Figure 2).

Major research stages

Pilot Study

A pilot study will be carried out to develop the empirical questionnaire. This is a critical stage to identify the significant ingredients that make up a quality project and the evaluation items for the quality performance.

Questionnaire Surveys

The pilot questionnaire survey will be drafted to test the factors leading to, and the criteria adopted in assessing the quality of a construction project. The pilot survey participants will review the empirical research questionnaire and their comments will be incorporated to develop the final questionnaire.

Face-to-face Interview Surveys

The face-to-face interview survey will be carried out to identify the quality practice in Hong Kong. The targets of interview include client's organization, consultant firm, contractor, sub-contractors and suppliers.

Case Study Method

The case study method will be carried to collect the actual information in the industry. It investigates a contemporary phenomenon, which is vital to the viability of research study.

Data Analysis

The result of the questionnaire survey and interviews will be analysed to explore the participants' view on quality projects. Various statistical techniques such as Kendall's Coefficient of Concordance, factor analysis, and multiple regression analysis will be used to analyze the research findings. The Statistical Package for the Social Sciences (SPSS) will be used to handle the statistical calculations.

Research Documentation

A comprehensive report will be compiled to document the major findings of the study. Recommendations for implementation and suggestions for further studies will be made accordingly. This research will add to the body of knowledge in the context of the factors that contribute to the quality performance of a housing project.

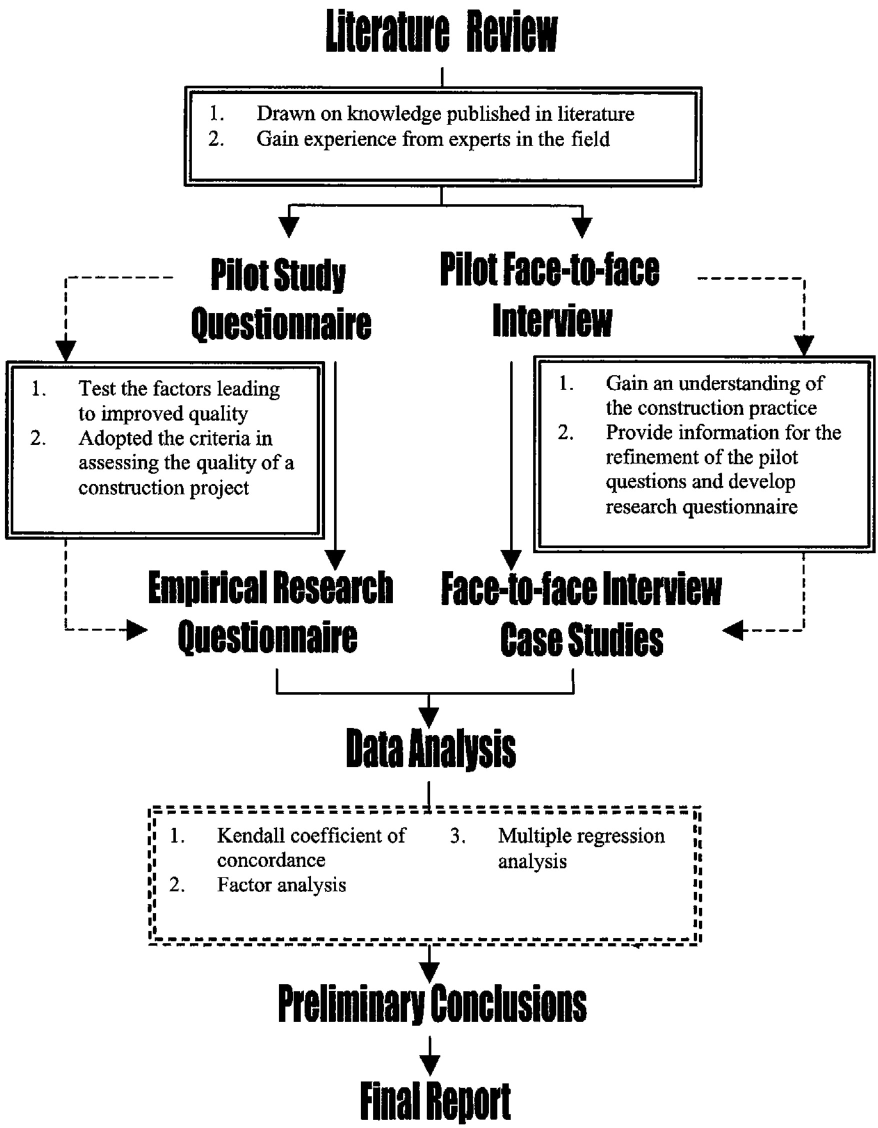

Figure 2. The research framework for this study

CONCLUSION

This paper is an interim report on an on-going research of analyzing quality systems in Hong Kong. It reviews the quality development in Hong Kong and the significant ingredients that make up a quality project. The research framework illustrates the research process and research methodology. The proposed research will comprise of the pilot study, questionnaire surveys, face-to-face interviews and case study. A triangulated approach will be adopted to ensure data validity. Various analytical techniques will be also used to derive findings for the research study.

It is envisaged that findings emerged from this study are crucial to establish a comprehensive model to link the causal relationship between the critical success factors (CSF) and the quality outcomes. Similar research studies can be conducted in other geographical locations to facilitate national and international comparisons.

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An Evaluation of Safety Measures in the Hong Kong Construction Industry Based on Total Quality Management PrinciplEs

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ABSTRACT

Safety is one of the most difficult issues facing the Hong Kong construction industry. The accident rate in construction is reported as highest when compared to other industries. In this paper, the current government-mandated safety management system in the Hong Kong construction industry has been evaluated using Total Quality Management (TQM) principles. The safety problems and their underlying causes are identified and then analyzed under different organizational structures. A set of TQM principles is suggested in the paper in order to solve the safety-related problems. A survey was conducted among some selected construction companies in

an attempt to test the findings. Based on the results of the survey, a set of recommendations is outlined for facilitating the adoption of TQM principles in the existing safety management programs of construction organizations.

CONSTRUCTION SAFETY IN HONG KONG

The construction industry's share of the total work force in Hong Kong is about 12%. According to the statistics provided by the Labor Department (Occupational Safety and Health Branch, 2000), the number of reported accidents in construction industry were 46% of the total number of reported accidents in all industries in 2000 as shown in Fig. 1.

The Hong Kong Government is taking serious steps to improve safety situation in the construction industry. In 1999, a new legislation was introduced (Factories and Industrial Undertakings (Safety Management) Regulation, 1999) which inevitably changed the traditional safety practices. However, the accidents rate in construction industry is still higher and proactive steps should be taken to prevent accidents from happening and set-up a safe working environment.

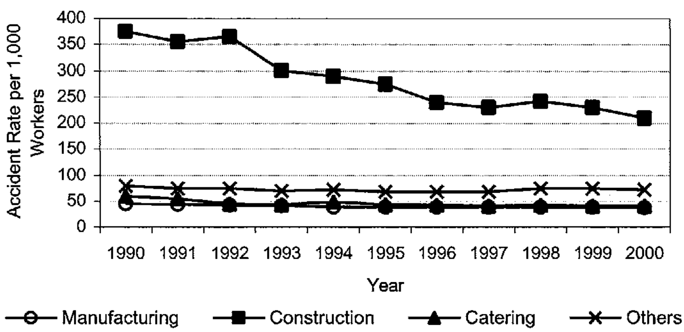

Figure 1 Industrial accident rates in major industries of Hong Kong

SAFETY PROBLEMS AND THEIR UNDERLYING CAUSES

According to the statistics from Labor Department (Occupational Safety and Health Branch, 2000), the major types of reported accidents in construction industry in 2000 are shown in Fig. 2. There were 56 fatality cases and most were related to workers working at height.

To investigate the reasons behind highest fatality accidents of persons falling from height, the Construction Industry Training Authority and Labor Department had conducted a series of case studies (Construction Industry Training Authority and Labor Department, 1997), which are summarized in Table 1.

To determine the root causes of the safety problems, Abdelhamid and Everett (2000) suggested a safety model called "Accident Root Causes Tracing Model (ARCTM)". ARCTM indicates that accidents occur due to three root causes.

I. failing to identify an unsafe condition that existed before an activity was commenced or developed after an activity was started.

II. deciding to proceed with a work activity after the worker identifies an existing unsafe condition; and

III. deciding to act unsafe regardless of initial conditions of the work environment.

The ARCTM model is based on the premise that the unsafe conditions were produced due to four causes:

I. management actions or non-actions.

II. unsafe acts of worker(s) or co-worker(s).

III. non-human related events; and

IV. an unsafe condition that is a natural part of the initial construction site conditions.

Thus ARCTM model underscores possible contribution of both management and labor towards safety. The domain of management and labor contribution to the accidents process falls within the characteristics of an organization. Dawson (1992) defined organizations as collections of people joining together with some formal association in order to achieve group or individual objectives. She identified six key aspects, which contribute towards safety management plan of an organization as follows:

People Aspects

The lack of training, knowledge, discipline, and motivation are people related problems. Some examples of such problems are: poor attitudes, inconsistent behavior, lack of intrinsic motivation, unwillingness to work and unclear ideas about safety.

Strategy Aspects

The strategy aspects cover problems like lack of commitment, planning and review. These aspects are directly linked with the company's vision and mission. Safety is a core issue and should be given a top priority while setting up goals and objectives for a particular project.

Technology Aspects

The construction industry has always gained advantage from new technologies to improve construction methods and techniques. However, the proper training of labor is very critical while using any new technology to avoid any mishaps.

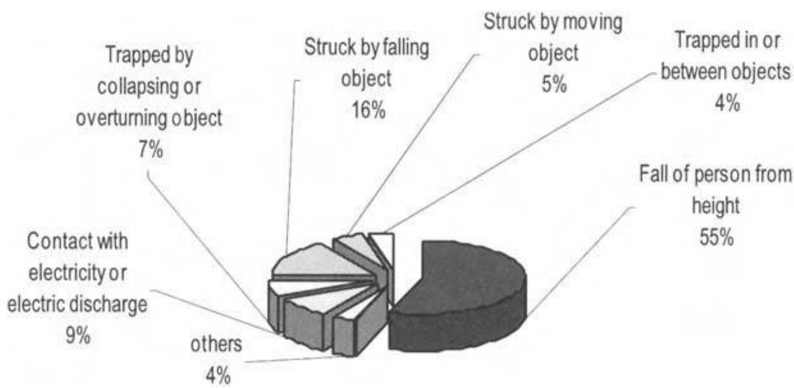

Figure 2 Types of accidents in Hong Kong construction industry during 2000

Table 1 Causes of accidents of persons falling from height

The Case	Causes and Contributing Factors
Collapse of a wooden platform erected inside a lift shaft	• Deterioration of the individual components of the platform • Displacement of the platform from its support due to severe vibration • Additional burden of debris and rubbish tipped on the platform
Person falling into an unprotected caisson	• Sloping ground with loose rocks • Lost of balance • No suitable barrier
Fall of person through broken roof	• Unsuitable and insufficient safe access
Falling through an unprotected lift shaft opening	• Unfenced lift shaft opening • Inadequate lighting
Falling from a substandard working platform	• Working platform not fully covered with suitable planks (void spaces between planking) • Lost of balance
Falling from an unfenced working platform	• Working platform without proper guide rail • Lost of balance
Wooden platform collapsed during dismantling	• Displacement of the platform from its support during dismantling • Lost of balance
Falling from a scaffold at height	• Unsuitable and insufficient safe access.

Environment Aspects

The change in environment (both internal and external) affects an organization greatly. Internal environment is controllable while in contrary; the external environment is more vague and required great attention to react. Changes are now taking place in construction safety management systems. Various new concepts and procedures are to be implemented. The construction companies are required to act as proactively as possible in order to sustain their operations.

Structure Aspects

The problems of lack of planning, instruction, inspection, maintenance and controls are related to the structure aspects. The structure of an organization refers to the socially created pattern of rules, roles and relationships that exist within it.

The organizational structure in many organizations is bureaucratic with central control. Many accidents occur as a result of lack of actions to resolve the problem in timely manner.

Cultural Aspects

The problems of lack of commitment and lack of discipline start with the culture. Some examples of such problems are: workers/sub-contractors have no loyalty; workers do not accept responsibility for safety; reluctance to prepare substantial documentation; management behavior to just fulfil the contract requirements rather than improving the safety system; and multi-layered sub-contracting system.

EXISTING SAFETY MANAGEMENT SYSTEM IN HONG KONG

In 1999, a new safety management system was approved by the legislative council of Hong Kong (Factories and Industrial Undertakings (Safety Management) Regulation, 1999). To facilitate proprietors and contractors, 14 process elements are introduced as following:

I. A safety policy that states the commitment of the proprietor or contractor to safety and health at work.

II. A structure to assure implementation of the commitment to safety and health at work.

III. Training to equip personnel with knowledge to work safely and without risk to health.

IV. In-house safety rules to provide instructions for achieving safety management objectives.

V. A program of inspection to identify hazardous conditions and for the rectification of any such conditions at regular intervals or as appropriate.

VI. A program to identify hazardous exposure or the risk of such exposure to workers and to provide suitable personal protective equipment as a last resort where engineering control methods are not feasible.

VII. Investigation of accidents or incidents to find out the cause of any accident or incident and to develop prompt arrangements to prevent recurrence.

VIII. Emergency preparedness to develop, communicate and execute plans prescribing the effective management of emergency situation.

IX. Evaluation, selection and control of sub-contractors to ensure that sub-contractors are fully aware of their safety obligations.

X. Establishment of safety committees.

XI. Evaluation of job related hazards or potential hazards and development of safety procedures.

XII. Promotion, development and maintenance of safety and health awareness in a workplace.

XIII. A program for accident control and elimination of hazards before exposing workers to any adverse environment.

XIV. A program to protect workers from occupational health hazards.

Proprietors or contractors with 100 or more workers, as well as construction projects with contract value of $100 million or more, are required to adopt at least first 10 elements of the safety management system, and to conduct safety audits of their safety management system. Construction projects with less than 100 workers are required to adopt first 8 elements of the safety management system. Project with less than 50 workers are exempted for the time being.

SAFETY IMPROVEMENT USING TOTAL QUALITY MANAGEMENT (TQM) PRINCIPLES

Over the past two decades, Total Quality Management (TQM) principles have gained worldwide acceptance in all types of industries, and implementation of TQM systems have helped many companies to increase their competitiveness, effectiveness, and productivity (Kerzner, 1994).

Safety improvement begins with the systems-thinking approach. The systematic approach of safety management is somewhat similar to the approach of TQM. Hence, with the adoption of core TQM principles and procedures, existing safety management systems could be vastly improved. A simple illustration of the way in which a safety system could be evaluated and improved using TQM principles is provided in Fig. 3 (Weinstein, 1997). Figure 3 illustrates that different domains of a safety management system can be systematically improved using TQM principles and procedures.

As suggested by Weinstein (1997), there are number of applications of TQM principles that are helpful to occupational or work safety. According to the scope of this research, selected TQM concepts and techniques have been identified which are to be integrated with the existing safety management system. Each of these concepts is adapted to a TQM style management system in which the forces on customer's focus, leadership commitment, and employee empowerment drive a continuously improving system.

Suggested TQM principles to assist the planning as well as implementation of the safety management system are illustrated in Table 2. Problems identified in the previous section are considered as primary factors for improvement.

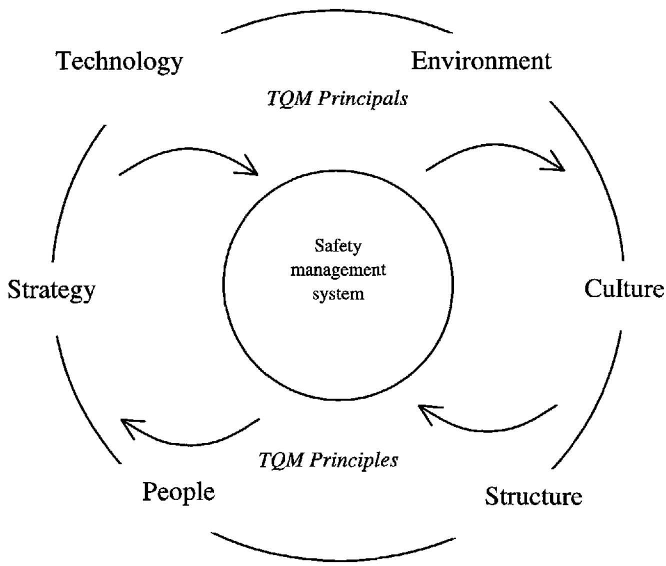

Figure 3 Safety management system improvement framework using TQM principles

Table 2 Suggested TQM concepts and techniques to improve construction safety

Safety System (14 process elements)	Primary Problems/Factors for Improvement	Areas to be Improved	Suggested TQM Principles
Safety and health policy	Lack of commitment, lack of discipline	Leadership, culture, commitment, employee involvement	Customer focus, company culture, Leadership commitment
Safety organization	Lack of planning and control	Leadership commitment, employee involvement	Leadership commitment, effective communication
Safety training	Lack of knowledge, lack of training	Leadership commitment, knowledge, skills	Leadership commitment, 5S*, coaching skills
In-house safety rules	Lack of planning and control, lack of training	Planning, control and review, culture	Quality planning and management
Safety inspection	Lack of inspection	Planning and control	Statistical process control
Personal protective equipment	Lack of communication and training	Planning, employee responsibility	Employee responsibility
Accidents/incident s investigation	Lack of information, lack of control	Planning and control, management by facts	Statistical process control, cause-effect diagrams
Emergency preparedness	Lack of planning and control	Planning and control	Quality planning, structural problem solving methods
Evaluation, selection and control of sub-contractors	Lack of commitment, lack of discipline	Leadership commitment, culture	Customer focus, company culture
Safety committees	Lack of commitment, lack of discipline	Leadership, culture, employee empowerment and involvement	Company culture, Leadership commitment, effective communication
Risks assessment	Lack of planning and control	Planning, control and review	Failure mode effects, analysis, fault tree analysis

Safety and health promotion	Lack of commitment and knowledge	Leadership, culture, commitment	Company culture, benchmarking
Process control program	Lack of planning, control and supervision	Planning,, control and review	Quality planning and management
Health assurance program	Lack of planning, poor knowledge	Planning control and review	Quality planning, problem solving steps
Safety resources	Lack of commitment	Leadership, commitment	Leadership commitment

There are three major categories of TQM principles selected. These are people oriented, management type and process related. People oriented principles are customer focus, company culture, and leadership commitment. Management type comprises effective communication, leadership and commitment, responsibility, benchmarking, 5S (seiri (organization), seiton (neatness), seiso (cleaning), seiketsu (standarization), and shitsuke (discipline)), coaching, quality planning and management. Process control techniques consist of structural problem solving and planning tools such as Pareto diagram, cause and effect diagram, affinity diagram, matrix diagram, control charts and statistical process control (Associated General Contractors of America, 1993).

VALIDATION OF FINDINGS THROUGH QUESTIONAIRE SURVEY

A questionnaire survey was conducted to evaluate the general understanding of TQM principles in the construction industry, and the extent to which TQM concepts and techniques can be implemented to improve the existing safety management system.

The questionnaire survey was conducted among selected general building contractors who were registered with the Building Authority of Hong Kong. At the end of 1999, there were a total of 416 whose names were published in the Hong Kong Special Administrative Region Government Gazette No. G.N. (S) 152 of 1999 S.S. No. 4.

Method of Survey and Sampling

The questionnaire consisting of 23 questions (opinion statements) based on existing 14-elements safety policy was prepared. A 6-point Likert Scale was used to elicit respondent's degree of agreement or disagreement and their knowledge about TQM concepts and techniques.

The initial questionnaire was pre-tested by a safety manager and a project manager of two construction companies. The final questionnaires were sent to the selected 70 companies (with more than 300 employees) during the month of March 2000. There was no specific period set for receipt of response. The respondents were asked to respond as soon as possible. Reminders were sent out to all respondents at the end of April 2000. The response rate was 41%. The survey data was analyzed using SPSS software for computing statistics, comparing groups, analyzing variability and testing hypothesis.

Survey Findings

The results of the survey indicated that the majority of respondents (65%) had prior knowledge about TQM principles and showed their interest in adopting the TQM techniques to improve their safety management system. The responses are indicated in Table 3.

CONCLUSIONS AND RECOMMENDATIONS

The result of this study shows that the basic TQM principles such as leadership commitment, safety culture, and continuous improvement can be applied to improve the existing construction safety management systems. However, there is a strong indication that some TQM techniques such as statistical process control, structural problem solving, and benchmarking are not directly applicable to the construction safety systems and must be revised to make them more compatible with the construction industry.

Table 3 Response about adopting TQM principles to improve construction safety

Safety System (14 process elements)	Response
Safety and health policy	Unanimously, all respondents agreed on the following statements: • The safety and health policy forms a part of the company core values. • The safety and health policy contains objectives for safety and health commitment relevant to the organization goals. • Commitment of safety culture is strongly indicated by the respondents.
Safety organization	95% of respondents agreed that a safety organization should be formed with knowledgeable personnel to achieve work safety objectives.
Safety training	75% of respondents agreed on the statement that all managers should go through proper safety management training. 15% of respondents disagreed on that statement and 5% of respondents opted for "Don't know".
In-house safety rules	Majority of respondents agreed on the concepts of continuous improvement.
Safety inspection	55% of the respondents indicated that they have used statistical tools and methods to analyze the results of safety inspections.
Personal protective equipment	90% of respondents agreed on the statement that the workforce should be knowledgeable and be given responsibility of ownership.
Accidents/incidents investigation	55% of respondents indicated that statistical process control, causes-effects diagrams or similar statistical tools are usual methods used for investigation of accidents and incidents in their companies. They strongly supported the use of such methods in the entire construction industry.
Emergency preparedness	Majority respondents indicated their doubtfulness of applying TQM techniques to formulate safety procedures. They suggested that the 'structural problem solving methods' may not be the best methods to prepare the safety procedures.
Evaluation, selection and control of sub-contractors	75% of respondents agreed on the statement that evaluation; selection and control of sub-contractors should be conducted through matching with alignment of company safety objectives.
Safety committees	All respondents agreed on the statement that a safety committee should be formed to monitor safety performance in different companies.
Risks assessment	35% of respondents agreed that the risk assessments on work processes should be conducted using failure mode effects analysis, fault tree analysis, or similar methods. However, many respondents were not familiar with such techniques but showed their interest to learn them.

Safety and health promotion	60% of respondents agreed on the statement that employees must know the results of accident & injury investigations and follow up actions.
Process control program	70% of respondents agreed on the statement that works should be planned, and controlled to meet safety objectives.
Health assurance program	Majority respondents indicated their doubtfulness of applying TQM techniques to develop health assurance program. In fact, problem-solving steps may not be the best methods in preparing such program; they should be used in conjunction with planning tools.
Safety resources	Majority respondents disagreed that safety resource is typically depended on contract value. A commitment to minimum safety resources is not strongly indicated.

The survey results indicate the following:

- Majority of respondents observed that the top management commitment, safety culture, continuous improvement and training concepts are useful to improve the safety management system.
- Majority respondents have a traditional thinking of meeting safety requirements just to fulfil the minimum contract requirements.
- Seldom use quality tools or analytical techniques in solving safety problems.

The survey results do not reveal any fundamental differences in opinions between groups of construction companies classified in term of their sizes. There were no indications that larger companies understand more about TQM principles.

It is recommended based on the results of this study that a further analysis of detailed application of TQM principles to the safety management consisting of training programs, skill development, improvement model, work study should be conducted. It is important for the construction companies to understand the concepts of TQM and its applications to the safety management for continuous improvement. The merits of having such an improvement system set up may commensurate with the real benefits gained from the system.

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A national system for certification and registration of construction enterprises' competence in Finland

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This paper introduces a system for impartial evaluation and registration of construction enterprises' competence by the Construction Quality Association, an industry-wide cooperative effort of the construction and real-estate sector. Its aim is to limit the grey market and make construction produce better quality primarily by offering audited information to clients looking for partners.

More specifically, the paper sheds light on the entity's three subsystems: Certification of competence on the basis of fulfilment of legal obligations and capabilities, Evaluation of the operating procedures of an enterprise, and Utilization of feedback from clients on a project basis in a systematic way. The prevalence of the system's use, its usability, and likely future development are also dealt with.

***Keywords**: Benchmarking, Competence, Contractor Selection, Client Feedback, Finland, Qualification, Quality Audit*

INTRODUCTION

It has long been the custom in construction to select implementers solely on the basis of the lowest bid, which has created problems and disputes. Entry into construction is easy and there is an abundance of unqualified bidders. Competition based solely on the lowest bid leads to grey markets and other irregularities. The general operating procedure also favours incompetence and undermines functioning cooperative relationships and customer service and impedes development of the sector.

Although sector advancement requires more thorough change in operating procedures, an approach that seeks to screen out possible "problem enterprises" among bidders can be considered a first step. Also, evaluation of previous projects and operating procedures lays a foundation for the selection of good enterprises independent of whether the final selection is based just on price or a combination of the above-mentioned factors, among others, and price.

This kind of selection is made possible in Finland primarily by the system maintained by RALA, the Construction Quality Association (Rala 2001). RALA is a joint association established by the central players of the construction market based on the above-mentioned principles. It is independent and evaluates and registers impartially the competencies of enterprises. Its members include all the key construction and real-estate sector associations and federations representing clients, contractors and consultants. The various ministries linked to the construction sector also take part in the association's activities.

The comprehensiveness of the activity and the wide support enjoyed by the organization justify calling it national, although it is not a body established by authorities to regulate activity, but a form of cooperation satisfying the sector's own needs. Its aim is to limit the grey markets and make construction produce better quality. Also, joining this system (by suppliers) as well as insisting that contracting partners (by clients) are approved by it is up to the actors of the sector.

The strategic cornerstones of RALA's activity are presented in more detail in Fig. 1—the selected methods for achieving these goals are given in the middle. The same three methods (systems) are explained preliminarily in Fig. 2.

Figure 1 RALA's strategic goals (corner boxes) and selected methods (middle oval).

This paper focuses mainly on presenting just these three subsystems. Of the subsystems, *certification of competence* has been in use for a few years whereas *evaluation of operating procedures* and *utilization of feedback* are only about to be launched—this is the situation at the time of writing of this paper in October 2001. In conclusion, the paper will review other possible changes in the functioning of the system, not forgetting the present situation and the work having led to it.

CURRENT SYSTEM OF BASIC QUALIFICATIONS

The foundation of the entire system is *certification of competence* which is intended to identify enterprises that possess the basic qualities required to produce quality as well as to compile information on the enterprises for the market. The system's key task is to ensure that the enterprise meets its *legal obligations* as well as to provide other information related to *competence and technical qualifications*:

- *Legal obligations* are primarily related to the fact that in order to be eligible to join the system, an enterprise must be entered *1)* in the trade register, *2)* the withholding tax register and *3*) the VAT register. Also, the enterprise must have *4)* met its tax obligations, and *5)* paid up employees' pension contributions. When applying for the certification of its competence, an enterprise also provides RALA with a power of attorney which entitles RALA to acquire corresponding official information on said enterprise from authorities. The Association monitors system members' payment of taxes and pension contributions on a monthly basis; defaults are reflected in real time in the information of the system serving as the basis of competence evaluation.

- Other information concerning *competence and technical qualifications* pertains to, without going into details, some aspects of an enterprise's resources and implemented reference projects. Competence certification is sought for a certain or several business areas. The enterprise must present at least three reference projects from each area which cannot be more than five years old. New enterprises can, however, gain entry into the register for a fixed period under separate classification without reference projects. Special legal qualifications may also be required by work types/businesses. The financial requirement for a competent enterprise is that its capital and reserves are at least 50 percent of its share capital according to the most recent financial statements. All information pertaining to *competence and technical qualifications* is controlled when joining the system and subsequently in connection with the annual reapplication and evaluation.

In practice, the system is maintained by RALA's office which also prepares applications for processing by a broader-based evaluation board. The board is made up of representatives of clients, contractors and independent experts. Naturally, the established competence certification procedures control everything from informing of a decision, appealing (to the board of the Association) and, for instance, the duty to report any essential change in company-related information. At worst, not meeting the conditions leads to deletion from the register although there is also a less severe sanction which means an entry of negligence in the register.

Enterprises certified as competent receive a certificate and are simultaneously entered in a register of competent enterprises freely accessible on the Association's Web pages including search features. Thereby clients, among others, can search information on enterprises certified to be competent, for instance, based on

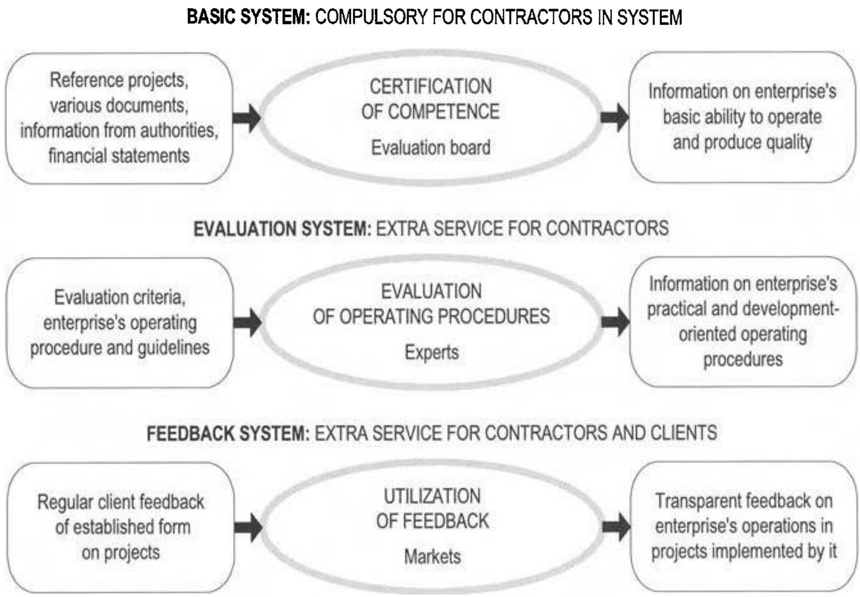

Figure 2 Selected methods for improving quality of construction.

business and operating area. Fulfilment of the enterprises' social/legal obligations has been ensured in a centralized fashion which eliminates red tape between various projects—earlier weaknesses included multiplication of the work load as well as deficiencies in up-to-dateness of information compared to the centralized system presented here. Publicity of information in the presented model also prevents dissemination of false information.

In addition to the above-mentioned information used to certify competence, an enterprise can also have other information—essential from the client's viewpoint—entered in the system. Table 1 gives an example of both types of information of an enterprise to the extent that the information is public and usable on Web pages—the application information proper is confidential. The presentation is somewhat condensed and modified as to appearance. Some information on the example enterprise has also been left out (marked [...]).

The main business of an enterprise is recorded using an extensive nomenclature which roughly adheres to that of the CEN draft standard (Qualification… 1999). A business may be a certain work type or, mainly on the project level, general contracting, construction management or design-build in the most comprehensive form. Reference projects representing the business area in question are also available for public viewing. One project linked to Table 1 is presented in Table 2 to the extent that information on it is publicly available.

INTENDED ADDITIONAL FUNCTIONS OF AUDIT AND FEEDBACK

Evaluation of operating procedures

A quality system with ISO9000 certification is often not a practical nor a realistic solution to the systematic quality improvement of SMEs as concerns its demandingness. In many cases a sufficiently reliable auditing system based on the sector's needs, which takes into account its typical characteristics, is certainly more practical, assuming that it supports the goals of developing an enterprise's operations and management in accordance with the quality prize criteria.

Table 1 Enterprise-specific example report.

Enterprise name	*Rakennustoimisto Pohjola Oy*		
Business ID	*0822967-8*	Domicile	*Tampere*
Company certification no.	*71*	*RALA member since 28 Sep 98*	
Oper. area – Search classification	*Metropolitan area, southern, central & northern Finland*		
	[...]		
– Subarea			
Telephone	*(03) 2356600*	Fax	*(03) 2356630*
Street address; post office	*Rautatienkatu 10; 33100 TAMPERE*		
E-mail	*pohjola@pohjolarak.fi*		
Internet	*www.pohjolarak.fi*		
Parent company			
Affiliated co.'s/subsidiaries	*[...] Pohjola Reconst Oy*		
Memberships	*Confederation of Finnish Construction Industries*		
Enterprise's main businesses for which RALA's competence certificate awarded			
Enterprise's main business		Business no.	Ref. no.
General contracting of new buildings and extensions		*17.1a*	*10, 11, 12*
General contracting of new buildings and extensions including design		*17.1b*	*13, 14, 15, 16, 17*
Businesses lacking sufficient number of references for last five years			
Enterprise's line of business		Business no.	Ref. no.
–		–	–
Special equipment and methods	–		
Special information	*Passes in use at sites.*		
	Regional offices: [...]		
Management	*Man.Dir. Juha-Eerik Metsälä, 34*		
	[...other key personnel including degrees completed...]		
Total staff		*82*	
– of which supervisors		*21*	
Total employees		*102*	
– of which vocationally qualified			

Level of quality assurance		*Enterprise-specific quality system*	
Tax debt and LEL pension debt certificate		*In order*	
Registered as VAT payer		*Yes*	
Extract from withholding tax register		*Valid until 28 Feb 2002*	
Year	2000	1999	1998
Financial period	*1.5.99-30.4.00*	*1.5.98-30.4.99*	*1.5.97-30.4.98*
Turnover, VAT 0% [€ mln]	*48.6*	*28.8*	*15.5*
Invoicing, VAT 0% [€ mln]	*43.8*	*31.6*	*21.0*
Wages [€mln]	*1.4*		
Salaries [€mln]	*1.4*		
Total wages & salaries	*2.8*	*0.9*	*0.5*
Profit before extraordinary items and taxes [€ mln]	*0.5*	*0.6*	*0.9*
Liquidity	*1.1*	*1.3*	*1.2*
Solvency	*0.23*	*0.35*	*0.36*
Business liability insurance		*€1.0 mln*	
Liability insurance covers the following businesses		*New construction, housing construction, structural engineering office*	
Projects entered as income		*On the base of degree of completion*	

Table 2 Example of a presented reference project.

Rakennustoimisto Pohjola Oy	*Reference project no. 17*
Main project / Locality	*Epilän nahkatehdas / Tampere*
Client / Contact person / Tel.	*YH-Asunnot / Seppo Malmi / [...]*
Content description	*Conversion of factory into residential building: 64 dwellings, 31600 m3 [...]*
Duration [mos.] / Year of completion	*15 months / 1999*
Contract price, VAT 0% [€mln]	*3.7*
Procurement method & payment basis	*Design-build/Turnkey project*
Share of subcontracting [%/no.]	*60 /20*
Additional information	*Design includes soil survey, architectural, structural, precast panel, heating, plumbing, ventilation and electrical well as other special designs. The project has been implemented based on contractor's design from the land-use draft to handover with 10-year liability also for design errors.*

RALA is in the process of introducing such a system which could be used to audit sector enterprises, especially SMEs. There are two alternative levels of comprehensiveness of the evaluation:

- The basic alternative targets the enterprise's site operations and related operating procedures; enterprise-level issues are not evaluated. Fulfilment of conditions set for practical procedures, which are important for the sector, is evaluated.

- The augmented alternative targets the operating procedure of the entire enterprise: in addition to site operations, also enterprise-level procedures are assessed. On the enterprise level, the fulfilment of key requirements for the enterprise's operations is evaluated also on the basis of quality prize criteria.

The factors to be evaluated are naturally many. Table 3 presents the main division of these factors: each numbered subsector generally includes a few subject fields (max. 10) which are the targets of evaluation. Evaluation according to the basic alternative covers only section *A* while the augmented evaluation covers both *A* and *B*.

Requirements are presented in the form of questions also on the self-evaluation form available on RALA's Web pages. Thus, the form also serves as a tool in the enterprise's internal development. Self-evaluation is intended to ensure that an enterprise's operating procedure is ready for the evaluation proper. As soon as an enterprise considers its operating procedure to meet the basic or enterprise-level requirements, it can apply for evaluation proper and subsequent approval.

The evaluation board selects evaluators for each evaluation (and follow-up evaluation) who must maintain confidentiality as regards evaluated information. The board grants approval on the basis of the evaluators' recommendation and issues a certificate of the same.

Approval of an operating procedure remains valid as long as the enterprise meets its related obligations. An enterprise must keep its operating procedure at a level that meets criteria and pass a biannual follow-up evaluation by an evaluator of the association—in off years it suffices that a passing self-evaluation is conducted and the association is informed about it. The enterprise is also obliged to notify its clients and the association of all changes that may affect the approval.

The aim of RALA's evaluation of operating procedures is to involve as many enterprises as possible in systematic and continuous development of their operating procedures in an increasingly client-oriented direction while ensuring that the basic standard remains realistic from the viewpoint of sector companies. Clients may also use the passing of an evaluation as a criterion in the selection of a supplier (cf. Table 1, item "Level of quality assurance"). Thus, certification is shown in the enterprise report of registered companies although there is still room for alternative procedures for verifying quality management. Inclusion in the register through certification of competence is a basic requirement for an enterprise to be evaluated by RALA's evaluation method.

Table 3 Subsectors of operating procedure evaluation.

A	*Production*	*B*	*Enterprise*
1.	site management	1.	management and development
2.	environmental and work safety	2.	bidding and contracting activity
3.	schedule management	3.	procurement
4.	cooperation		
5.	confirmation of legality of implementation		
6.	planning and development of activity		
7.	site management and subcontracting		
8.	equipment		

Utilization of feedback

Client feedback is a key factor in the development of activities. On the other hand, the contractor's ability to produce quality is emphasized in multi-criteria selection of a contractor. Typically, an attempt is made to anticipate this, not only on the basis of the earlier described technical qualifications and operating procedures, but also based on earlier success with projects. For this reason, the client feedback system has also been included as a field of RALA's development. Creation of a common procedure is especially important in construction where project organizations and collaborative relationships often are of one-off nature and sufficient continuity and comparability cannot be achieved without harmonizing feedback practices.

The basis of the feedback system is the standard evaluation which is part of each project. In practice, the client (owner, or general contractor in case of subcontracts) fills in a simple form at project conclusion and delivers it to RALA. Evaluated factors are shown in Table 4 (italicized items are subheadings). The scale used throughout is 1 to 5 (worst to best). Business ID (cf. Table 1) is used to link feedback to the information on the contractor in question (correctness to be checked). The procedure guarantees the following services for sector actors:

- *Supplier's feedback register.* The supplier can read feedback on his enterprise, both project-specific and summarized information in real time. Each enterprise can read only information about itself.

- *Benchmarking for suppliers.* Enterprises are compared against one another annually, and the results are put out as benchmarking reports which compare an individual enterprise's client feedback to the summarized information on similar enterprises. The service is confidential.

- *Client's own feedback register.* Clients who have provided feedback have the possibility of reading their own feedback information and summaries of it and can use the collected feedback systematically in their business.

- *Information on enterprises' competence.* All users can read about the strengths and successes of enterprises involved in the system. Yet, only scores above the sector average are linked to the enterprise report. (All individual items of feedback are, however, readable by the feedback provider and the receiver).

- *Joint quality index of entire construction sector.* Information related to sector client satisfaction based on all client feedback material will be published, for instance, by various sectors and businesses to be evaluated.

Information services are provided chiefly on the Association's Web pages where the parties can browse through information within limits of agreed access rights. Enterprise-specific feedback summaries are linked to the enterprise report (cf. Table 1) when there is a sufficient amount of feedback for individual feedbacks to remain unidentifiable.

The guiding principle in presenting client feedback has been to bring forth positive feedback. In connection with earlier attempts, systems that output all results have proved to be essentially unworkable since people have been unwilling to participate in them. It is also true that the discussion within the sector has been largely negative in spirit, which tends to become self-fulfilling. Thus, the primary aim has been to stress successes and create a stimulating atmosphere to produce better performances, while seeing to it that the information genuinely serves selection of partners and the development activity of enterprises.

Table 4 Items to be evaluated in the feedback system.

Quality ▪ Contracted work quality ▪ Management and implementation of agreed quality assurance procedures ▪ Workability of handover to oneself ▪ Quality of handover material and maintenance manual ▪ Degree of completion at handover inspection ▪ Repair of defects and deficiencies noticed during handover inspection *The environment and work safety* ▪ Cleanliness and order on site ▪ Management of work safety on site ▪ Management of environmental issues and related know-how on site (waste disposal, environmental protection) *Schedule management* ▪ Adherence to schedule in accordance with common agreements	*Cooperation* ▪ Capacity of supplier's personnel for cooperation ▪ Agreement about changes ▪ Tending to notices of defect ▪ Accessibility of supplier's staff ▪ Information flow on site ▪ Supplier's service level as a whole *Confirming legality of implementation* ▪ Tending to official obligations *Personnel* ▪ Skill of supplier's work supervisors ▪ Skill of supplier's workers ▪ Commitment of supplier's employees to set goals *Site supervision and subcontracting* ▪ Conformity of supplier's subcontracting to contract ▪ Tending to site supervision duties

CONCLUDING REMARKS

In the preceding, this paper presented a procedure for certifying and registering the competence of Finnish building sector contractors. The actual *certification of competence* part, which targets basic conditions, has been in use since spring 1998 and is accessible to all construction companies: general, sub- and specialist contractors. The number of enterprises having had their competence certified has been growing steadily. The system includes about 400 enterprises at the writing of this paper (October 2001), of which 280 are general contractors. The enterprises' combined turnover is more than € 5 billion and they employ over 30,000 people. A good 5,000 reference projects come under the system. The enterprise database gets 1,000 – 3,000 visits every week

The wide use of the system proves that it is needed and has been successfully implemented as does a recent client inquiry (Rala 2001: Ajankohtaista, Sep 25, 2001). Although it is not practical to go through the results in much detail, it is worthwhile mentioning that the procedures implemented by RALA were graded "very" or even "extremely" important. The workability of the various features of the implemented solution was considered "very good" on average. Further development of the system, again, was considered "very" or "extremely" important.

These development measures actually include the above *Evaluation of operating procedures* and *Utilization of feedback* packages. Said packages are not yet in regular use but are only being tested in a part of the project stock. Preliminary favourable experiences from the pilot stage do, however, suggest that they will soon be included in RALA's service package. Minor changes to what was presented above are likely.

Thus, even though the condensed format of the paper did not allow substantiation or analysis of the solutions, it is clear that they have been carefully thought out from numerous viewpoints, and above all from the viewpoint of practical needs, due to the large-scale involvement of industry. This applies to the certification of competence as well as the additional services presently examined in a pilot study. The development of services has involved practical actors in many working groups.

Furthermore, the development package is part of a broader development programme which supports the work, for instance, by examining different international practices (Lahdenperä & Sulankivi 2001). The programme also includes a project organized by clients that systematizes contractor selection from the viewpoint of an individual project (Rakli 2001), which for its part puts demands on RALA's system. As a result of the work, at least the following information necessary for contractor selection will be added to the competence-certification enterprise report:

- Work safety-related procedures of an enterprise (certified system, other systematic procedure, no systematic procedure, etc.).

- Level of environmental issues management (certified system, other externally audited system, enterprise-specific system, site-specific management of environmental issues, no separate procedure, etc.).

- Statutory competencies of individuals (number of competent site managers and work supervisors and designers in different fields of specialization).

Other possible near-term development areas include expanding the system into an e-business-based contractor selection system. The present immediate project feedback may quite soon be complemented with user feedback provided at the end of the warranty period.

All in all, the system has proved to be practical and it is being developed further so that it could play an increasingly central role in the development of quality-conscious construction (cf. Table 5).

Table 5 Benefits of various subsystems.

Certification of competence	Evaluation of operating procedures	Utilization of feedback
	Benefits to client	
▪ facilitates search for reliable and competent partner ▪ generates most information necessary for preselection and shortlisting ▪ intensifies monitoring of bearing of social responsibilities	▪ third-party evaluation ensures appropriateness of partner's operating procedures ▪ promotes sustained development of partner enterprise	▪ provides comparable information on enterprises' genuine competence ▪ supports selection of the most suitable contractor for the project ▪ facilitates selection based on overall economy
	Benefits to supplier	
▪ effective way to prove competence and be visible ▪ reduces routines required to monitor grey markets ▪ promotes healthy price formation in sector	▪ provides guidelines for development of operations ▪ advantageous way especially for SMEs to show quality of own operating procedure	▪ workable, resource-saving alternative for collecting feedback ▪ cost-efficient way of comparing own enterprise to competitors and monitoring development of both

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THE USAGE AND ADAPTATION THE LEAN CONSTRUCTION PHILOSOPHY IN BRAZILIAN CONSTRUCTION COMPANIES

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According to Souza (1996), "It is indispensable to perceive that the human being is the major element of transformation. It will give the competitiveness differential. The capital can be migrated and the technology could be acquired, but the development of the human being is essential".

With this in mind, it is not surprising to believe that the site workers represent the edge of the productive chain process, where will be applied all quality concepts that are transmitted to them (Amaral et al., 1997)

The national culture usually imports methodologies to analyze the organizational culture, which learns how to interpret individual organizations through methodologies that does not take in consideration the characteristics of its present culture, forgetting that the organizational culture comes from its national culture (Freitas, 1997).

THE NEW PRODUCTION PHILOSOPHY APPLIED TO CONSTRUCTION: LEAN CONSTRUCTION

The lean production system, as indicated by Green (1999b), consists in one complex cocktail of ideas, including continuous improvement, leveling of the organizational structure, teamwork, cutting off waste, efficient use of the sources and resources.

The study of the Japanese automobile industry production model began by the occidental industries with a clearly objective of becoming more competitive in the global auto market. For this purpose, the Japanese model was introduced in the United States of America boosted by the competitiveness, because the Orientals could sell better and cheaper cars dominating the American auto market.

Even though there are plenty competitive advantages on the Japanese model, Green (1999b) and others authors argue its applicability in the occident, principally because of its particularity with the Japanese cultural way of life.

JAPANESE INDUSTRY CHARACTERISTICS IN THE 1970'S

Yoshimoto (1998) points out some aspects of the Japanese quality management:

- The quality management is centered on the human being;
- The conventional management system is compound of a system of methodic and continuous improvement;
- The success of a management centered on the human being is based on the respect of the individual;
- The workers must work to develop theirs duties and improve their skills during the job;
- The workers should interact with all organization through their work and skills, allowing the development of their intellectual and creative potential.

Another aspect mentioned by Kenney e Florida (1988) apud Green (1999b) is that the Japanese industry has a different characteristic that found in others countries, wherein is observed as central point its cultural factor.

THE NEW PHILOSOPHY UNDER THE SIGHT OF THE HUMAN RESOURCES

The challenge that shows for the researches and professionals of the civil construction, is to adapt the concepts and principles of the Lean Production from the orient to the occident, trying to achieve better performance in its production processes (Hirota e Formoso, 2000).

Koskela (1992) began these studies and called this approach as the New Production Philosophy for the Construction. However, it is observed that some aspects related with the human resources are not being the focus of this philosophy.

The main point of its discussion is that this philosophy is based in control, management stress and exploitation. Facts that are proved in the Japanese industry reality, as is noted by Hutchinson et al. (1998) apud Green (2000), when they asked to the Japanese parents if they would allow their kids to work in the automobile industry. Only 4.5% of all parents interviewed, answered yes (Nomura (1992) apud Green (2000). The most cited reasons for not allowing their kid to work in this environment were: Low wages for an intense work (43%); Intensive work (41%); Lot of extra hours of work and holiday work (36%).

HUMAN RESOURCES – ONE MISSING ISSUE IN THE LEAN CONSTRUCTION

First will be presented points that are favorable to this cited philosophy. These points are essentially discussed by Howell and Ballard (1999):

- The production management is based in how the things are made and not how the persons are treated;
- The Lean approaching is a different way to manage the physical production, particularly to treat the dependence and variation effects;
- The Lean approaching tries to reduce waste, but this does not intend to add stress to the production process. It is reasonable to assume that the stress is derived from an inadequate answer for a global competitiveness;
- The Lean approaching offers a new way to organize the production, however the worker's exploitation could be a result of its application but not a requisite;

- The Lean production techniques, as an abstract theory, are nullified in terms of human resources management;
- Furthermore, Womack and Jones (1996) apud Green (2000) say that it could be applicable beyond the manufacturer sector.

At this point will be presented some negative points of this philosophy (Green, 1999a). The north of its discussion is that some researchers have ignored a relevant group of opinions related with human value, a missing point in the Lean approaching.

The Neutrality of the Lean Construction

Based on the argument presented by Howell and Ballard (1999) suggests that the Lean Production techniques are neutral, Green (1999b) instead says that such affirmation could be true, however any change in the organization generates disturbance in the status quo.

Exploitation and Stress

As said by Green (1999a) there is a significant contradictory literature that argues the Japanese management methods. The debate is pointed out to clarify if these methods are based on loyalty, job readiness and consensus, or if it is based on the stress generated by the management and exploitation.

The literature alerts for the consequences that it may bring in the quality of life. According to Green (2000) it is difficult to understand why these critics are being ignored so often. These critics are dated since Kanata (1982) described the Toyota success in the 70's.

Recently Sughimoto (1997) describes that the term "karoshi" is commonly used between the Japanese workers to mean sudden death and severe stress generated by the extra work hours (green, 1999a).

All things considered, it is surprising to confirm that the illness absence is barely identified in the Japanese industry (Sughimoto, 1997 *apud* Green, 1999b).

Japanese Culture

As indicated by Green (1999b), the Japanese works in the same company their whole life, it is an honor issue, they live to work and not work to live.

There is a hierarchy in the organizational structure but all workers have basics knowledge of the work and they love their company.

Protectionism of Japanese Culture

Green (1999a) suggests that there is a lot of hypocrisy in the western comments about Japan's industry success because of its market trading restrictions to others countries, saying that the American and European industries hegemony was based on the same trading restrictions principles.

Management by control

According to Garrahan & Stewart (1992) apud Green (2000), the environment is ruled by a growing management control and a continuous reduction of the worker's autonomy.

The organizations are required to work as pre-set machines to reach its goal.

COMPARATIVE STUDY BETWEEN JAPANESE X BRITISH X BRAZILIAN INDUSTRIES

Table 1 Mainly Differences between Japanese x British x Brazilian Industries

	JAPANESE	BRITISH	BRAZILIAN
Structure	Vertical	Horizontal	Vertical
Job relations	Loyalty to the company, the company is their family	High mobility at work, but there isn't on them, low search of avoiding the uncertainty.	High mobility at work
Work vision	Work is necessary, but not a goal on itself	Work is good for people	Work is just a way of family sustenance
Adaptability to the lean construction principles	Success in the transfer of ability	High level of disillusion in the transfer	There are few practical indications related to the building site.
Level of education	95% of the population had finished high school	Low level of education	Low level of education
Performance	Act under strong antecedent planning	Act under strong antecedent planning	Act without a lot of planning-improvisation
Commitment	Perfection is a point of honor	Large success to share the vision and goals of the project. People's capacities should be maximally utilized.	Perfection is a goal difficult to be reached
Management	The management is focused on the human being - respect of the individual.	The employees are just the force to implement the objectives in a more efficient way	Management is focused on the process control
Culture	The collective spirit is a	There is a cultural and	It is collectivist, even

	manifestation of the philosophical Japanese concept of the ego: the individual is not recognized apart from the general.	social powerful force, an elitist occupational structure. People in organizations behave as unattached individuals.	more than Japan. It is a country characterized by a huge distance of power.
Hierarchy	The structure of the companies is vertical. Multifuncional labor that also carries out planning and control activities (vertical enrichment)	Decentralization of decisions and informal coordination. Equity: work groups at all levels have been authorized to make decisions.	Tendency to the centralization of the power inside of the social groups. Paternalism for the moral and economical domain.
Personal relationships	The intellectual Japanese tradition is marked by the single humanity-nature, body-mind, I-other. The individual is not recognized apart from the general.	People have mutual respect and make the assumption that people are acting from honest and honorable motives.	Society based on personal relationships, proximity search and affection in the relationships. However, in spite of their necessity of being part of the group, they don't have strong collective spirit.
General characteristic for issue resolution	The employees, from the highest to the lowest hierarchical level, are committed to the continuous search of improvements. They are constantly observing what they do, looking for problems and comparing their acting with the other ones, trying to improve their performance	Requests for decisions have speedy response. People have pro-active attitude to informal needs. Errors are treated as lessons learnt and remediation shared.	Flexibility and adaptability as a way of solving problems - Brazilian knack. Mistakes are not treated as problems to be corrected

THE NEED FOR THE WORKER'S QUALIFICATION

The Brazilian construction industry was not concerned with its workers qualification due to the fact that it was not an important issue. The work force was abundant and the inflationary process led the organizations to invest in the capital instead of in the their human resources.

Changes in the national economy, and the globalization wave broke–up the existent paradigm forcing the construction companies to search for new technologies that substantially improve their productivity which imply to have specialized, skilled, and qualified workers.

Therefore there is a need for the worker qualification in response of the market's demand, and it is responsibility of both, employers and employees, to achieve better productivity rate through qualification of the workers.

To stress those points, it is important the concerning with the qualification of the construction workers because they represent the edge of the productivity chain process.

To a company operate in a different place struggling with cultural, language and environmental barriers it is necessary to utilize ease instruments that know in deep the local reality to adapt the way that the company works (Huermer e Östergren, 2000).

According to Seymour et al. (1997), there are various techniques that are utilized to improve the efficiency of the construction process, the goal is to successfully communicate these techniques. Cultural differences are recognized as barriers to reach this communication.

As stated by Amaral (1999) and Pereira Filho (1999) the valorization of the human being as a person or as a professional is extremely important when trying to reach positive results in the management of this kind of resource.

Maia (1994) affirms that to manage human resources consists in get people involved, increasing their participation, satisfaction, and motivation in order to obtain higher productivity and quality in the productive process.

Despite considered as the major resource of the companies, the workers receive less attention, and administrators and executives do not care for the necessity of giving them the adequate training for the work.

CONCLUSIONS

There aren't universal or standardized solutions. The constructive technologies are not transferable from place to place, in the same way of the environmental and social characteristics. The theories should be adapted to the particularities of the local culture and economy.

And beyond that, transform cultural differences, viewed as obstacles, to advantages for the transfer of that theory. It is still a goal to be reached. The erroneous attitude of simply adopting the theories should be rethought, and it is necessary to begin to adapt them to the local specificities.

There are several techniques that are used to improve the efficiency of the construction process. However, to communicate with success such techniques is still a group of subjects that deserve answers. Although the objective of the lean construction is not linked to the way as the people are managed, but as the production system works. The cultural differences, as well as the needs, values, abilities, the individuals' knowledge should be considered.

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Theme 6:
Construction Workforce Issues

PRINCIPLES OF WORKFORCE MANAGEMENT

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Much research has been conducted in the last decade on improving labor productivity. The focus has been on equipment reliability, material availability, coordination with vendors on prefabricated components, and other topics. However, most of the recommendations for improving performance have been applicable to industrialized countries with little emphasis on developing countries. Since the work in developing countries is mainly labor intensive (Thomas 2001), strategies are needed for improvement that do not require prefabricated components and the use of heavy equipment such as cranes, forklifts, etc.

OBJECTIVE

The objective of this paper is to present selected principles of workforce management that have evolved from measuring construction productivity and assigning productivity losses to specific causes. The projects, which form the basis for the principles cited, are from the U. S., Croatia, Turkey, and Brazil. The activities studied include formwork, steel reinforcement, and concrete placement on bridges, commercial buildings, and other structures. The principles are based on field observations and are applicable in industrialized and developing countries.

RESEARCH METHODOLOGY

The conclusions in this paper are based on observations of 14 concrete formwork projects and 12 steel reinforcement projects. Collectively, these 26 projects account for 104,343 workhours and 1,590 workdays. On each project, the daily workhours and quantities were documented. Other factors affecting the work were also recorded. The daily productivity and baseline productivity for each project were calculated. A project waste index (PWI) was calculated as a means of assessing good and subpar performance (Thomas and Zavrski 2000).

The factors potentially leading to losses of productivity were documented. The daily inefficient workhours were calculated and attributed to the factors occurring on that particular workday. In some cases, contractor records were consulted to verify the presence of certain events. The results were tabulated by cause. By noting the events and subsequent inefficiency impacts, it was reasoned that by following the principles cited in this paper, losses of productivity could be greatly reduced and labor performance could be dramatically improved.

PERFORMANCE MEASURES

It has been proposed by some that the appropriate measure of construction performance is construction output, that is, maximizing construction output will lead to improved performance. This viewpoint would favor the pressures associated with schedule acceleration. However, research has shown that contractors vary the amount of labor applied to an activity each workday depending on the amount of work available (Thomas 1999). Figure 1 illustrates the variability of daily workhours on a concrete formwork activity on an apartment

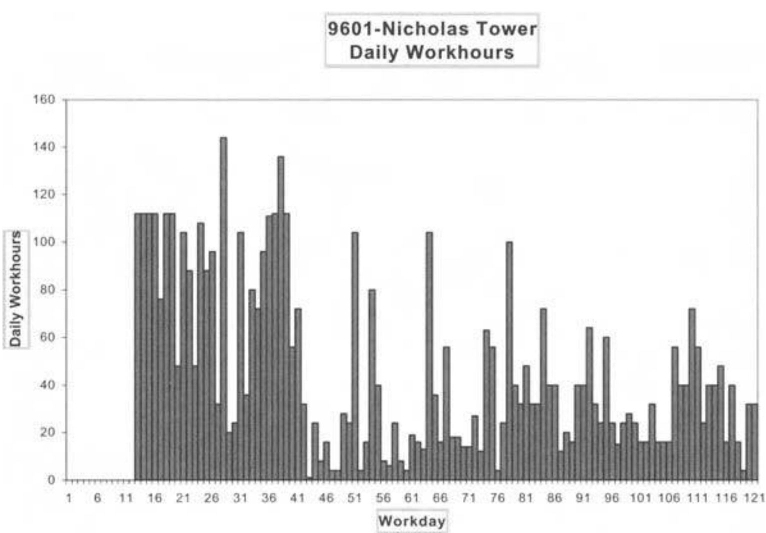

Figure 1. Daily Workhours, Project 9601.

building where the labor performance was exceptionally good. Since both workhours (input) and quantities (output) will vary daily on a typical project, *the most appropriate measure of performance is labor productivity defined as the input divided by the output.*

The productivity on a particular activity needs to be put into context. This is done using a project waste index that is defined as:

$$\text{Project Waste Index (PWI)} = \frac{\text{Cumulative Productivity} - \text{Baseline Productivity}}{\text{Expected Baseline Productivity}} \quad (1)$$

This parameter is explained in more detail in other articles (Thomas and Zavrski 1999, Thomas et al. 2001). *The PWI is an effective analytical measure of the waste associated with a particular activity.* The PWI can be used to differentiate superior and subpar labor performance.

Writings on lean construction state that the way to improve performance is to reduce output variability. However, an examination of the daily productivity on 14 concrete formwork activities has shown the this hypothesis is not entirely correct for construction operations (Thomas et al. 2001). Rather, the goal in construction operations should be to *reduce the variability in labor productivity.*

ELIMINATE DISRUPTIONS TO IMPROVE FLOW

Lean construction proponents correctly promote the view that by improving flows, performance will be improved. Lean flows relate primarily to the availability of materials and information. In construction, flow improvements also encompass equipment availability and in some instances, labor availability.

In the study of formwork on four bridge sites in Central Pennsylvania, the disruptions affecting the work were noted and the inefficient workhours were calculated. The results in Figure 2 show the total inefficient workhours by cause. As can be seen, labor, equipment, and information flows are the leading causes of labor inefficiency. Thus, *minimizing or eliminating disruptions will reduce the variability in labor productivity and will improve performance.*

WORKFORCE MANAGEMENT PRINCIPLES

Figure 2 shows a bothersome trend, that is, the largest number of inefficient workhours on the six projects is associated with the labor resource. These are by no means the only projects in which similar trends have been observed. By studying the factors leading to the performance degradations, it is possible to formulate principles of good workforce management. These principles are discussed below.

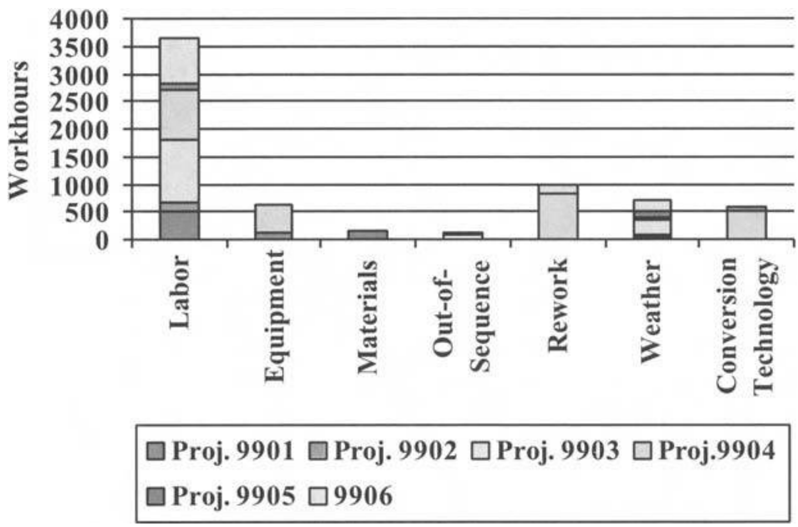

Figure 2. Summary of Inefficient Workhours by Cause.

General Principles

Construction activities usually consist of multiple subtasks. The relative effort of subtasks needed to produce a unit of output is described by rules of credit (Thomas 1998). Table 1 shows the subtasks and rules of credit for concrete formwork and structural steel erection activities. As can be seen, the erection activity in both instances yields the highest credited output.

Table 1. Typical Subtasks and Rules of Credit.

Concrete Formwork		Structural Steel	
Subtasks	**Rules of Credit**	**Subtasks**	**Rules of Credit**
Erect	0.75	Erect	0.60
Plumb and Align	0.15	Plumb and Align	0.30
Stripping	0.10	Tightening	0.10
Total	1.00	Total	1.00

Suppose one determines that in order to maintain good daily productivity, it is important to be credited with 1,200 ft^2 of formwork each day. Therefore, a crew must erect 1200/0.75 or 1,600 ft^2 in a single workday in order to receive credit for 1,200 ft^2. Conversely, if stripping is the only daily activity, the crew must strip 12,000 ft^2. This simple example shows that an important principle of workforce management is to *make the focus of the crew's work directed to "high revenue producing work,"* in this instance, formwork erection. Many construction activities have been observed where most of the daily work was on "low revenue producing work." However, the good projects are the ones where "high revenue producing work" is the main effort each workday.

In developing countries, much of the work is labor-intensive. The labor component is frequently assigned to material handling. Sweis in a study of mason productivity in Jordan found that the productivity for skilled labor was nearly the same as in the U.S. and UK. The difference in productivity was in the unskilled productivity. It took much more unskilled labor to unload, stockpile, and transport the materials to the work face. This relationship is shown in Figure 3. Thus, efficient material handling and timely deliveries are important for good productivity, especially on labor-intensive operations.

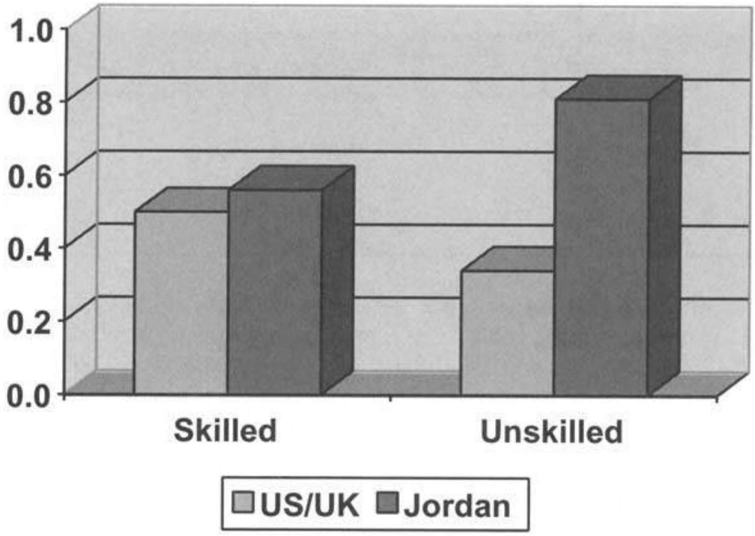

Figure 3. Comparison of Masonry Productivity.

It is recognized that other subtasks such as stripping of formwork and tightening of bolts is necessary. Additionally, there are other incidental tasks that need to be preformed, like cleaning of forms, bolting of steel, site cleanup, and others. However, there is always time for these subtasks to be performed. Consider another example involving a crew of six carpenters. For the erection of wall formwork, the following manpower requirement for each subtask is assumed: erection-4 to 6 carpenters; bracing, plumbing, and alignment-2 to 3 carpenters; and stripping- 2 carpenters. If during the day, the erection subtask includes modular panels and bulkheads (a task requiring maybe two carpenters), then there are theoretically 4 carpenters available to perform other work. This situation may last for several hours. The under utilized members of the crew can perform stripping, cleaning of forms, or site cleanup while formwork erection, which is the "high revenue producing" task, is still being performed. Thus, an important principle is to *work on 'low revenue producing' subtasks concurrently with' high revenue producing work.'* There is always time during the day to do so.

A corollary to this principle is to *perform incidental work concurrently with' high revenue producing work.'* An example is worthwhile to illustrate this principle. A highly efficient framing crew was observed during the construction of condominiums and townhouses. Unfortunately, the crew deferred the incidental task of cleanup (see Figure 4) until the production work was nearly complete. At the end of the activity, it took three workdays to clean the site, thereby eroding much of the profit generated by the productive crew. This is illustrated in Figure 5.

In other work, it has been observed on numerous occasions that the daily output for the crew was minimal for no readily obvious reason. Clandestine inquiries revealed that the work that day was poorly planned. The crew foreman or the site superintendent had failed to arrange a necessary event or resource. Thus, the crew was left at the site with little or no work to perform. In instances where there is little for a crew to do, send the crew to another task, another project, or home. It is important to *staff the work with labor resources that are consistent with the amount of "high revenue producing work" available to perform.*

Figure 4. Illustration of Poor Housekeeping.

Multiskilling

Multiskilling refers to a crew that performs multiple tasks that would ordinarily be assigned to several crews. An example of multiskilling is when one crew erects both concrete formwork and steel reinforcement. On workdays when both activities are in progress, the challenge is to allocate a portion of the crew to each activity. To do so, one must assess the amount of work available for each task and base the assignments on an acceptable output for the workday. Assignments can be made for parts of the day.

As an example of effective multiskilling, consider the productivity curve shown in Figure 6 for a crew erecting a concrete basement wall. The crew performed formwork erection, steel reinforcement installation, and concrete placement. The superintendent moved crewmembers from one task to another based on the work available. He also made sure that the teams were sized so as not to impede progress. The results in Figure 6 indicate that the work was very productive.

In another less than successful application of multiskilling, crews on four bridge projects erected abutments, foundations, piers, and pier caps. The crews performed formwork erection and placed concrete. Figure 7 shows the crew productivity for the days in which concrete was placed on four projects and the size of the concrete placement. In general, the daily productivity improves as the size of the placement increases. For smaller size placements where the crew work assignments were split, the contractors had difficulty in properly allocating individual assignments and/or assuring productive work for both work teams. From these data, it is concluded that *where concurrent multiskilling tasks are applied, crew assignments need to carefully consider the size of the teams, the*

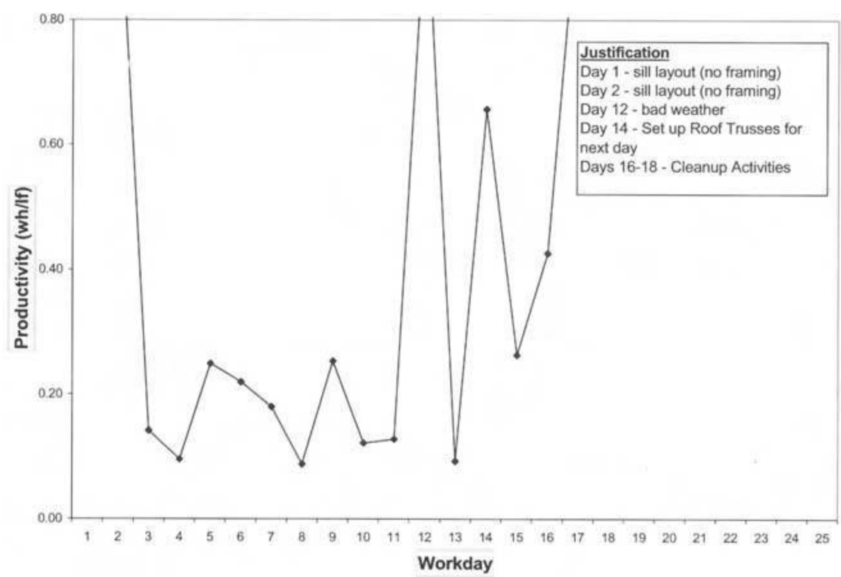

Figure 5. Productivity of Framing Crew.

production output to be expected for each team, and how many hours the team should be given to accomplish their respective work.

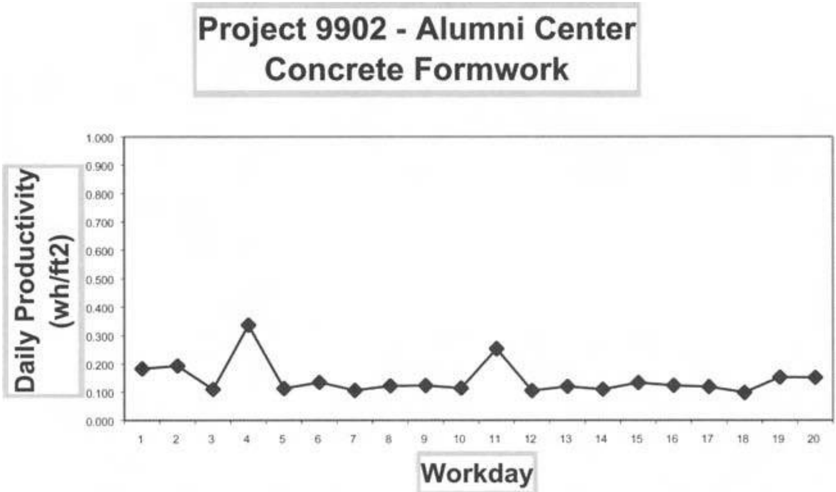

Figure 6. Daily Productivity of Successful Multiskilling.

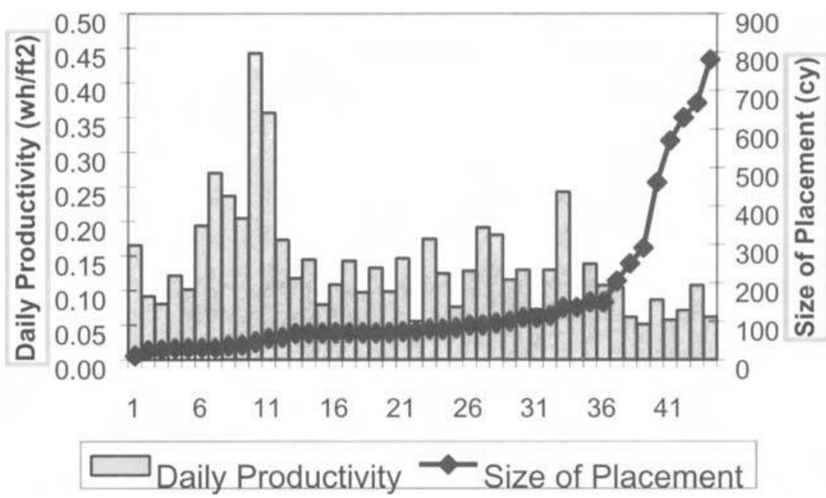

Figure 7. Productivity vs. Size of Concrete Placement.

Suppose a formwork crew of 6 craftsmen are to place 25 cy of concrete. The productivity budget is 0.090 wh/ft^2 expressed in terms of equivalent ft^2 of wall formwork. If the conversion factor for concrete placement is 7 ft^2 of formwork per cy of concrete, then the equivalent amount of formwork for the 25 cy is 175 ft^2. At the budgeted rate, the concrete placement should take 15.75 or 16 workhours. If the placement is scheduled to take 4 hours, then 4 craftsmen should be assigned to the work. The remaining craftsmen should be assigned to other work. The others should produce the equivalent of 89 ft^2 of formwork. After 4 hours, the teams can then be merged to perform additional "high revenue producing" work.

Symbiotic Work

Symbiotic work is work that done by several crafts. Therefore, the work is cooperative in nature. An example illustrates this concept. For the erection of a wall in an office building, a framing crew erects the wall frame followed by an electrical crew that does roughin electrical. Insulation and drywall crews complete the wall before the electrical crew returns to do the finish electrical work. The work of the electrical crew is symbiotic or cooperative whereas the framing crew's work is sequential. The framing crew can work at its own pace whereas the pace of the other crews is likely to be dictated by others.

The key productivity issue whether a crew can establish it's own pace. Where there are numerous activities and the production rate of the tasks is highly variable, the only hope of establishing one's own pace is to assure that there are adequate time buffers between each activity.

Research has shown that managing symbiotic activities is more difficult than managing sequential ones. Symbiotic relations can sometimes be avoided by using prefabricated components. Also, schedule constraints can shift some activities from sequential to symbiotic. Construction methods can also be designed to be sequential. Obviously, *because of the management difficulties, it is important to avoid symbiotic relationships.*

Because of the uncertainties of variable production rates and the exposure of construction to disruptions, it is important to maintain adequate inventories or stockpiles of materials and components. In a study of the productivity of steel reinforcement crews in Brazil, it was documented that the crew productivity was better with higher inventories. This relationship is shown in Figure 8.

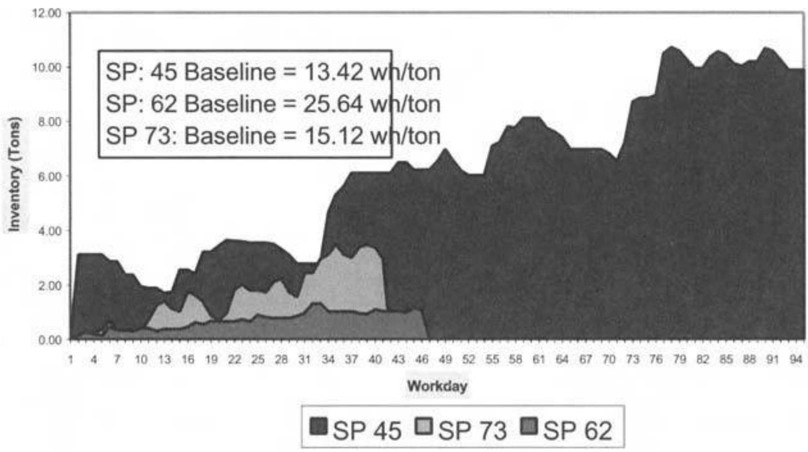

Figure 8. Relationship Between Productivity and Inventory.

Schedule Acceleration

Schedule acceleration occurs when project management attempts to increase daily production (output) beyond normal capacity. This is usually done by applying scheduled overtime, hiring more craftsmen, or creating a second shift. According to lean thinking, maximizing output is synonymous with improved performance. However, improving output performance is most often done at the expense of worsening labor performance. Accelerated schedules have been associated with losses of labor productivity of as mush as 200%. A typical range is 25–50%.

Three projects from Brazil involving steel reinforcement were compared to three projects in the U.S. and one in Turkey. The three projects in Brazil were subjected to the pressures of schedule acceleration. All six projects used prefabricated steel. The average crew sizes and cumulative productivities are given in Table 2. Figure 9 shows the output per day as a function of crew size. Figure 10 shows the daily output vs. labor productivity. Both figures suggest that increasing the output will likely lead to degradations in labor performance.

Table 2. Daily Output, Crew Size, and Cumulative Productivity.

Project	Crew Size	Daily Output (tons/day)	Cumulative Productivity (wh/ton)
9901	2 - 3	0.86	10.16
9903	6 - 8	1.88	12.19
9904	6 - 8	2.64	14.33
9905	3 - 4	1.61	11.14
SP 28	6	0.88	36.67
SP 101	5 - 8	0.70	40.66
SP 120	10 - 12	0.72	71.89
TK 1	4	2.00	12.77

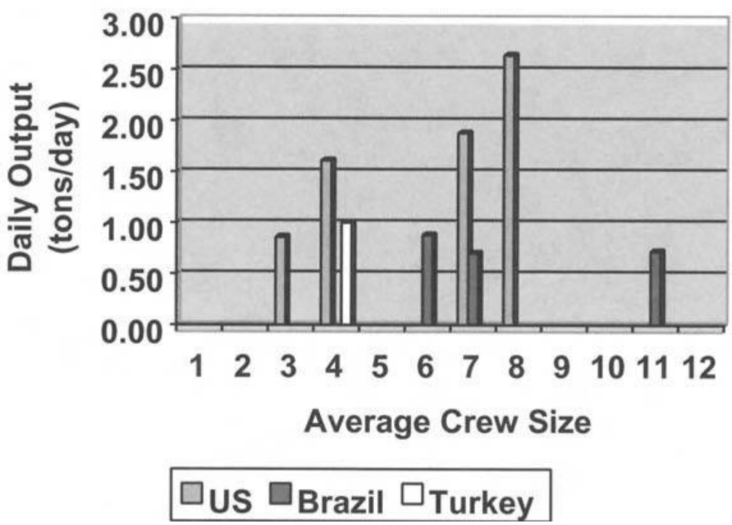

Figure 9. Crew Size vs. Daily Output.

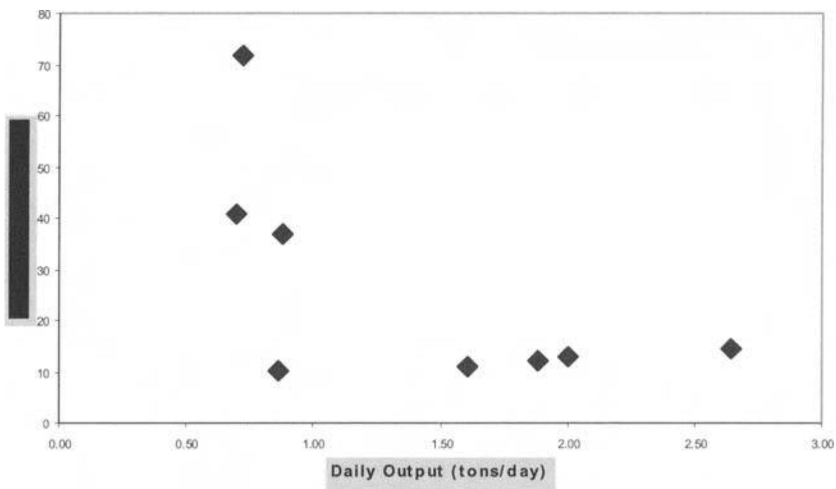

Figure 10. Productivity vs. Daily Output.

To further illustrate the difficulties associated with schedule acceleration, consider Figure 11 that shows the formwork productivity on a two-story parking deck. Between workdays 12 and 28, a work schedule of 70 hours per week was used. However, during this time, the labor productivity degraded by about 40% while the average daily output increased by only 15%. The data from this project and the projects listed in Table 2 show that *the emphasis on output is misguided and that increases in output are usually accompanied by degradations in labor performance.*

Figure 11. Illustration of the Negative Consequences of Schedule Acceleration.

CONCLUSIONS

The application of effective workforce management principles are necessary to assure good construction performance. This paper has used actual construction data to illustrate the negative consequences of poor workforce management principles.

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Attracting and Retaining a Skilled Construction Workforce

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ABSTRACT

Perhaps the greatest challenge facing the worldwide construction industry over the next decade will be attracting and retaining qualified workers at all personnel levels. There presently exists shortages of qualified craftworkers, field supervisors and project managers in many countries. This situation is expected to continue even in downsizing economies.

This paper will present the major causes of the inadequate supply of qualified craft workers along with findings from recent research on what companies having a low rate of turnover are doing to attract and retain craft workers and the resulting positive impacts. Even though the information to be presented is the result of research conducted in the United States, the reader will find it applicable to construction companies worldwide.

CAUSES OF SHORTAGES OF QUALIFIED WORKERS

According to research sponsored by the Construction Industry Institute (Liska and Piper, 1999) and conducted by Clemson University's Department of Construction Science and Management, the following reasons were found as to why there is a shortage of qualified workers in the construction industry:

- Smaller number of new work force entrants due to lower birth rates.
- Existing workers not changing careers to construction due to the unattractiveness of the industry.
- Current Immigration Laws

Lower birth rates are the direct result of women having less children and/or children later in their life due their increasing priority of maintaining a professional career. According to the U.S. Department of Labor about 60% of working age women are in the work force today in the United States. The number of women in the work force is expected to increase. The Hudson Institute (1998) projects that by the year 2020, 50% of the workforce will be comprised of women in the United States.

In terms of the image problem, it is well known that children begin to consider careers in the 5th grade. At this time they are not selecting careers in which they may be interested but are discarding those in which they are not. There are many factors that influence their decisions of which careers to discard. These include:

- What the child hears, reads and sees
- Parents
- Guidance counselors
- Teachers and others

What a child reads and sees concerning the construction industry is usually considered negative. These include:

- Reading about accidents
- Seeing unorganized and unsafe job sites
- Seeing unkept and unprofessional workers
- Hearing about the difficulty of the work and the conditions of the workplace
- Hearing about poor wages and benefits and a lack of job security
- Being counseled not to select a career in construction by parents and elementary and high school
- counselors

These and other reasons serve to paint a poor image of the construction industry in the minds of young people when making career decisions. This has been reinforced in many surveys conducted in the United States. In 2000, the *Jobs Rated Almanac*, published by the *National Business Employment Weekly*, high school seniors ranked construction worker as 248 out of 250 as a career choice. According to this survey, construction worker ranks lower than roustabout and cowboy, and higher than only dancer and lumberjack. Furthermore, in the above noted CII sponsored research, 1500 construction crsftworkers of various ages and experiential levels were asked if they would recommend their trade to their children. About 70% responded negatively. Therefore, these and other similar studies conducted throughout the world indicate that the construction industry needs to first take steps to improve its image if it is to attract and retain qualified workers.

Improving the image of the construction industry is an inside out approach, in that it must begin with each and every person in the profession. Construction workers at all levels can help to improve the image in the following ways:

- Conduct themselves professionally in dress, language and behavior both on and off project sites
- Be trustworthy and maintain a high level of integrity
- Be principled-centered in their professional and personal life

The next step to improving the image of the construction industry is for workers to work together to improve their companies. This includes:

- Creating a trusting culture within every company
- Aligning company goals and values with worker goals and values
- Meeting worker expectations
- Developing effective formal programs to attract qualified workers
- Developing effective formal programs to retain productive workers

The final step in improving the image of construction is for companies to work together and through construction trade and professional associations and institutes and other organizations to promote the industry as one that offers a meaningful and challenging career to potential and existing workers.

Individuals, companies and other organizations are working alone and together to improve the image of the construction industry in the U.S. and other countries throughout the world. The largest effort in the United States is being led by the National Center for Construction Education and Research in Gainesville, Florida.

This national coalition of 20 nationally recognized construction associations has developed a comprehensive image improvement effort including an annual live broadcast to elementary and high schools and the development of an extensive career path with supporting training and educational curricula.

FOUNDATIONAL ATTRIBUTES TO ATTRACTING AND RETAINING QUALIFIED CRAFT WORKERS

The previously noted research conducted by Clemson University resulted in the identification of five foundational attributes necessary to attract and retain construction craft workers. These, in order of importance, are:

- Pay wages and benefits competitive with construction and other related industries
- Provide job security to the extent possible
- Provide a safe working environment
- Treat workers fairly and with respect
- Provide good working conditions

Age of worker, years of experience, type and size of company, geographic location and whether union or non-union did not make a difference in the composition of the above list.

Paying Competitive Wages and Benefits

According to the previously mentioned CII research study, wages and benefits in the construction industry have not kept up with wages and benefits in other industries in the United States nor inflation as a whole. Construction companies must take action to correct this situation. In any hiring considerations, companies must take the time to determine what workers in similar positions are receiving in terms of wages/salaries and benefits. This must be done for both positions within the region in similar types of construction companies and companies in other industries that utilize the skills and knowledge of individuals being sought. Companies can acquire this type of information either through available governmental or private agencies or by conducting their own wage/salary and benefit survey.

Providing Job Security

Job security relates to the desirability of maintaining continuous employment, which is a common expectation among most workers to meet economic related needs. Actions construction companies can and are taking to provide job security especially for their craftworkers include:

- Developing and implementing annual staffing plans
- Providing cross or multi-skill training
- Sharing workers
- Working with owners in scheduling major project startups

Of all the above actions, the one that appears to have the greatest potential of helping to insure a higher level of job security among craftworkers is multiskilling. Multiskilling is a labor utilization strategy in which workers possess a range of skills for more than one work process and are used flexibly. The Construction Industry Institute (1998) has conducted research on this subject and has found that multiskilling has many benefits to the industry, project and craftworker. The benefits to the industry are:

- More effective utilization of the workforce
- Improved employment opportunities
- Labor cost savings - 5% - 20%
- Reduced total installed costs

Project benefits of multiskilling include:

- Fewer workers needed - 35% average reduction
- Flexibility of work assignments
- Increased acceptance from workers
- Increased worker motivation
- Improved project safety importance

Worker benefits of multiskilling are:

- Longer, more stable employment - 46% average increase
- More marketable workers
- Increased earning potential
- Greater variety of work
- Fewer relocations

Provide a Safe and Healthy Work Environment

Since the passage of the Occupational, Safety and Health Act in the early 1970's, safety has improved on construction sites in the United States. Unfortunately, there has not been significant improvement in all sectors of the industry. In order to help attract and retain construction craft workers the industry needs to do more to maker projects safer. The Construction Industry Institute sponsored research (1993) resulting in the identification of 170 attributes necessary in all construction safety programs. In addition, the Zero Accident project, identified five attributes that were found to make the difference between a project with a good safety record from one that had an excellent safety record. These attributes are:

- Pre-project/Pre-task planing
- Safety orientation and training
- Written safety incentive program
- Alcohol and substance abuse program
- Accident/Incident investigation

Treat Workers Fairly and With Respect

The demographic makeup of the workforce in the United States is changing. Some of the major changes identified by the Hudson Institute (1998) are as follows:

- The average age of the population will increase to beyond 40 by 2020.
- Only 16% of the workforce is between the ages of 16 and 24.
- The percentage of U.S. born white males in the workforce is about 16% whereas it was 47% in 1988.

- By 2020 50% of the workforce will be women.
- Immigrants will represent the largest share of the increase in population and the workforce.
- Non-whites makeup 30% of the new workforce entrants which is twice as much as in 1988.
- By 2040 25% - 30% of the workforce will be Hispanic.

With these and other changes comes a whole different set of worker values and expectations. In addition, in no time in history have there been so many different generations in the work place. Whereas it has been traditional for a younger person to be supervised by an older, more experienced individual, this is no longer the case. As individuals come out of retirement to seek employment, younger individuals are serving as their supervisors. While at the same time, older, more experienced individuals still in the workforce, continue to supervise new younger entrants. This changing employee-supervisor relationship brings with it a whole new set of challenges to the relationship due to the different, and often times conflicting, values and expectations of the individuals. There has been much written about the effects of generational differences in the workplace and how to effectively manage it (200). Supervisors and managers must become aware of the generational differences and, in turn, become more flexible in selecting the most appropriate leadership style. In summary, supervisors and managers must become skillful in practicing participatory management techniques.

Some of the more important attributes and expectations of the future workforce are:

- Expect more leisure time
- Be less educated than existing workers
- Desire to work part time or share a job with another person
- Need more flexible working hours
- Be retired and seeking a second career
- Be physically and/or mentally challenged
- Be bilingual
- Be part of a two-income family

- Be a single parent
- Work two jobs on occasions
- Want more opportunities for development and benefits
- Dislike repetitive work
- Want to be more involved in decision making
- Desire feedback on their performance

Provide Good Working Conditions

There are many things companies can do to provide good working conditions for their field workers. These include:

- Maintain organized work sites
- Provide rest periods and lunch breaks
- Provide clean break and lunch areas
- Maintain heated/cooled work space
- Provide cool portable drinking water
- Implement and enforce dress and language codes of conduct
- Post and enforce discrimination and harassment policies

IMPACT OF TURNOVER

Turnover is defined as those individuals who quit voluntarily or are terminated for cause. It does not include those laid off due to completion of work, sometimes referred to as reduction-in-force. The previously mentioned CII sponsored research (1999), found that turnover negatively impacts productivity. In addition, the same study found that for each 10% increase in turnover, labor costs increase by 2.5%. Finally, earlier research conducted at Clemson University (1986) found that for each case of turnover, an average loss of 24 hours results due to such things as having to find and train a replacement worker, administrative tasks of terminating one person and hiring another and indirect causes such as loss of productivity. Many contractors, today, feel the loss has increased to 30 to 36 hours per absence.

MOST COMMONLY USED RETENTION PROGRAMS

An unpublished study conducted by the Construction Industry Institute Work Force Retention Implementation Feedback Team in conjunction with the previously noted CII study (1999) found that construction companies were trying many things to retain craft workers. The techniques most used were:

- Training and re-training
- Improving working conditions
- Building morale
- Paying overtime

When the same companies were asked which of the techniques they were using were felt to be most effective in retaining craft workers, the following were noted:

- Paying retention bonuses
- Improving working conditions
- Conducting multi-skill training
- Training and re-training
- Paying overtime

Finally, the companies were ask to identify the most cost effective techniques they were using to retain craft workers. The major ones were:

- Building morale
- Implementing re-employment plans
- Paying retention bonuses
- Training and re-training
- Conducting multi-skill training
- Conducting exit interviews

The reader should note that most of the techniques contained in the three above lists answer to the five foundational attributes to attract and retain craft workers previously presented in this paper. Furthermore, the reader should note that paying overtime, though an effective means of retaining workers because of the additional wages they are making, is not cost effective. The reason is that after 4 to 6 weeks, in the same overtime schedule, productivity falls off 10% for each 10 hours overtime worked per week. And, therefore, remaining in an overtime schedule, as a means of retaining workers will only have a negative impact on overall labor costs. It may be more effective to increase the wages of workers an amount equivalent to the overtime rate, and work the normal 40-hour week.

ATTRACTING AND RETAINING CRAFT WORKERS

The previously noted CII sponsored research (1999) found that those companies experiencing annual rates of retention of 80% or better were experiencing:

- Expected profits on more projects
- Completion of more projects at or ahead of schedule
- Better project safety performance

Furthermore, the same study found that these construction companies were all doing certain things that the other companies in the study were not. In terms of attracting qualified workers, the companies were:

- Implementing the five foundational attributes
- Recruiting at trade schools, high schools, and community colleges
- Pursing reduction in force workers
- Working with other contractors for hiring
- Recruiting outside of their respective project locations
- Using written and performance tests in the hiring process

In terms of retaining craft workers, the companies were:

- Implementing the five foundational attributes

- Conducting needs assessment to train continuously
- Conducting continuous supervisor human relations training
- Tying wage progression to skill improvement
- Providing long-term preferential treatment to tenured workers

The 80% rate of retention and the techniques contained in the above two lists can serve as benchmarks for construction companies. Unfortunately most construction companies do not monitor their rates of retention. And if they do, it is only by project and they rarely utilize the information in a more comprehensive manner to identify overall causes and trends.

Therefore, before a company can begin to improve their rate of retention, they need to develop a process by which to capture the necessary data to calculate rate of retention by project and overall and to determine why the turnovers have occurred. Acquiring the data is doing nothing more than putting in place a reporting system to determine how many total people are on a project each day and how many of them were terminated for cause or quit voluntarily. From this data, the rate of retention can be calculated and monitored.

The other component is to determine the reasons why people left. For terminations for cause, the reason(s) are known. For voluntary quits, the appropriate person in the company needs to conduct an exit interview using a standard form to document the results, if, in fact, the person is accessible to participate in it. Many companies will retain the last paycheck until the person leaving participates in an exit interview or completes a standard form indicating why they are leaving. It should be pointed out that this idea often does not work depending on what day of the week workers get paid and the day the worker quits. Furthermore, one needs to carefully analyze the reasons provided as to why a person is leaving a company because they may not be accurate for personal reasons.

CONCLUSION

Attracting and retaining construction craft workers continues to be the number one challenge faced by the construction industry in the United States and in other countries. Research has shown that companies, who devote time and other resources to implementing the five foundational and other key techniques, experience many benefits, which in turn makes them more competitive in the marketplace not to mention their ability to grow.

From the research findings discussed in this paper, along with proven techniques being utilized by construction companies, the following can serve as a checklist that companies can use to attract and maintain a qualified workforce.

- Conduct a company-wide "generation analysis" to determine the current makeup of the organization.
- Identify sources for future workers
- Match known values of the different generations with company work force and sources for future
- workers.
- Identify and implement attraction techniques that are consistent with values and expectations of
- workers.
- Place workers in positions that provide them with the opportunity to succeed keeping in mind their
- values and expectations.
- Identify and put into place retention techniques that are consistent with the values and expectations of
- the workers.
- Monitor and manage retention rates.
- Conduct annual training needs analysis for all supervisors and managers to insure they are "generational
- savvy."
- Provide and/or support needed training on a continuous basis for supervisors and managers in
- "generational differences" and how to effectively supervise/manage a diverse workforce.
- Conduct annual training needs analysis for all other employees.

- Provide and/or support needed training for all employees on a continuous basis.
- Tie successful completion of training and successful application of newly learned skills and knowledge
- to wage/salary increases and other rewards.
- Develop career paths for all employee
- Conduct annual formal performance evaluations
- Provide benefits, incentives and rewards meaningful to the respective generations.
- Work to improve the image of the construction industry individually and with others.

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Management and Organisational Cultures at the Construction Site

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INTRODUCTION

"Construction is not developing at the same speed as others sectors. A number of factors like culture, organisation, regulation and lack of competition are as a whole implying that innovation is hampered" (Danish Government analysis of construction, opening sentence, authors translation Bygge/Bolig, 2000).

This paper discusses organisational cultures at building sites. Cultures are viewed as shared meanings and common symbols and are, in contrast to the common view that culture is a hindrance for production, seen as a condition of possibility for management and production. Management and organisation of construction site continue to rely largely on informal coordination between a larger number of contractors, crafts and individuals. Although public but also some observers might think that this kind of organisation is inefficient, we find interest to discuss the cultural embeddedness of this organisational form, viewing it as a combined strength and weakness for management of construction site. The *empirical part* reports on an exploratory study of organisational cultures at a Danish building site (Christensen, 2001). The method used is ethnographic, three teams of craftsmen and the site management team were followed with participant observation. The craftsmen teams were carpenters, masons, and the team for assembly of prefabricated concrete elements. The results highlight the multiplicity and ambiguity of cultures. The site as a whole represented one relatively weak common culture, which coexisted with at least four different cultures. This multiple configuration of cultures follows patterns of crafts, employment relations but also cuts across structural differentiation. The common culture partly relies on the contractual relations. The *implication for management* of building site is to refrain from imposing a strong singular culture and to replace this by an understanding of the necessary coexistence of multiple cultures. The *paper is structured* as follows. Initially the method and the theoretical frame are presented. Then each of three analytical perspectives, integration, differentiation and ambiguity, is discussed and a combined culture conceptualisation is offered. Case material from a Danish building site is then presented, where the configuration is formed by at least five cultures. Finally the discussion and conclusion sum up.

METHOD

The method used can be labelled as ethic ethnographic (Martin, 2001) although they were some limitations. The time available was limited (see below). Three teams of crafts and the site management team were followed with participant observation (Emerson et al, 2001). The craft teams were the masons, the concrete element –team and the carpenters. These teams were chosen, as they were active when the observer visited the site. Access was negotiated, and the decision on looking at the mentioned teams was taken with the agreement of the project manager. The observer followed the site for two months. Each craft team was observed in one work week (five days). The management team was observed for three days. A number of key actors on the site was interviewed through the two months period (Heyl, 2001). Finally the observer participated in site coordination meetings and four health and safety committee meetings. The site study organisation encompassed organisational structures, history, occupations, management tasks, skills and other aspects of the organisation (Clegg et al, 1996). Svend Christensen, which carried out the observations, had quite a few explicit reactions to his presence, which led him to downplay his observation role; the use of notebook was thus dropped. The author visited the site once and observed the three craft-teams and participated in a coordination meeting. The (symbolistic) ethnographic approach which is adopted here is characterised by an open set of concepts used by the ethnographer in the fieldwork (Geertz, 1973). The ethnographer looks for three types of symbols; verbal, physical and acts. The verbal symbols encompass metaphors, myths and narratives, as well as meaning and interpretations, regarding shared meaning. The physical symbols can be equipment, materials, pictures and the like. Finally also observed actions expressed in a ritual form during daily work are important. The ethic ethnographer is expected to exercise empathy with the field and at the same time create sufficient distance to the observed in order to capture elements of everyday understandings and practices, which had been normalised or become routines (Emerson et al, 2001, Heyl, 2001). Since the culture analysis relies on one workweek present for each of the teams, it can be questioned whether a sufficient inner understanding has been obtained (Schutz, 1972). As Alvesson notes, there needs to be more than a singular occasion backing each of the findings up. The results must therefore be regarded as explorative. Other methodological problems have arisen because the approach used relies partly on the members' oral discourse. The teams followed were in contrast largely mute during their practices, putting emphasis on symbolic actions and patterns of routines. In contrast the breaks gave information to an analysis of rhetoric.

ORGANISATIONAL CULTURES

Organisational culture studies have been dominated by two main paradigms: functionalism (Schein 1987 a.o.) and interpretivism (including symbolism, Geertz 1993 a.o.) (see also Parker, 2000, Alvesson, 2001, Schultz, 1990, Martin, 2001 for reviews, the presentation here draws on Koch and Richter, forthcoming). The approach adopted below represents a modified version of symbolism. Culture is here perceived as a perspective on organisation. Focus is on symbols, which can be expressed verbally, physically and by actions. However, along with other observers, we would be cautious not describing these paradigms as too distinct (Martin, 2001, Parker, 2000). Moreover the definitions and analysis of culture, developed below, is clearly selective, designed in a way that is "practical" and slightly unique in comparison with other studies. We have sought to appropriate the concepts to our object of study, which is a building site, where actors, including workers and management with relations to the production processes, were in focus. We thereby adopt a position similar to Alvesson (2001) and Clegg (fo) who observe that culture studies have to be carried out in a specific context. Such studies do not and cannot operate with an entirely stable set of concepts, independent of setting.

Organisational culture is the shared and learned meanings, experiences and interpretations, expressed partially symbolically, which guide actions in everyday routine. Culture(s) is in interaction with social structures within and outside the organisation. In our first works on organisational culture in other sectors we found a resonance between empirical experiences from Danish manufacturing and the IT-sector and especially Alvessons argument for culture differentiation within organisations. In the development of organisational culture theory on the other hand, there continues to be controversies on the way to conceptualise and analyse culture (Martin 2001). Rather than too easily taking one-sided position in these debates, we found Martins suggestion of a three perspectives analysis promising, especially with the extension Alvesson offers by synthesising the perspectives into the concept of multiple configuration. This allows the scholar to handle quite complex cultural patterns. In this paper the three perspectives differentiation, integration and ambiguity are used to analyse the cultures at a building site.

Integration

Within the integration perspective culture is the shared understandings in a given organisation. There is a consistency across cultural manifestations (Martin, 1992). Schein is probably the most significant scholar within this perspective, for as he notes, "one finds little variation within a cultural unit" (Schein, 1992: 22). Culture is thus an integrative mechanism, labelled as the social glue between its members (Schein, 1992, Alvesson, 1993, 2001). In Scheins version the common basic assumptions is the consistent shared element.

Some representatives of the integration perspective clearly link it with managerial prerogatives and attempts of top-down control and change of the culture (Peters and Waterman 1982, Deal and Kennedy, 1982, Hofstede, 1991). Within this position it is rarely recognised that several cultures are in play. If so it is interpreted as a signal of weakness (Gregory, 1983 commenting on Peters and Waterman, 1982, Deal and Kennedy, 1982), or one culture is assigned the role as dominant, whereas others are represented as subcultures. As Parker rightly argues it is often a matter of perspective what is subordinated and what is superior.

Differentiation

This perspective focuses on the lack of consensus between interpretations, experiences and assignments on meaning in organisations. Researchers within this perspective have often paid considerable attention towards non-leader centred sources of culture (Parker, 2000, Louis, 1985, Martin, 1992). "Differentiation"-researchers differ, however, in their analysis of which lines of differentiation should characterise the field. Several authors thus present analysis, seeing culture as a product of social structures like countries, enterprises, departments, professions and groups. These different groups coexist in the organisational culture studied. Moreover it is often argued that some cultures are superior to others, the "others" being seen as subcultures. Parker (2000: 188) in his study of three organisational cultures presents three types of (overlapping) divisions: Spatial/ functional (different buildings and departments), generational and occupational/ professional. Other studies like Alvesson's focus on the everyday work practice producing local cultures. These can cut across social structures. He advocates for a more cautious approach in the interpretation of differentiation in cultural manifestations. He thus argues for an analysis, which discriminates social structural differences from cultural ones.

Ambiguity

Seen from the differentiation perspective, cultural manifestations are ambiguous. There is a lack of clarity. Potentially there are differences in meanings, interpretations of symbols etc., which are incommensurable and irreconcilable (Martin, 1992, Frost et al 1991, Alvesson 1993). Moreover in the continual process of creating and recreating meaning, members of different cultures might orient themselves differently at different times (Parker, 2000: 89). This perspective thus acknowledges the uncontrollable uncertainties that provide the texture of contemporary life (Martin in Frost et al 1991). Alvesson (and Parker) however, warns against too easily assigning cultural phenomena to ambiguity. Thus pointing out that ambiguity might originate from social structures or social practises. Drawing on Bourdieu, Alvesson (1993) introduces social fields to represent a professional grouping with a distinct field of activity and qualifications, with its own rules for success and recognition and its own structure of positions and economic and symbolic rewards. He thereby seeks to create an analytical dimension where social structures interact with and co-produce the culture. Feldman (1991), drawing on March operates with the following ambiguities: ambiguity of intentions, understandings, history and organisation. In this study the focus is on ambiguity of intentions using an appropriated version of the framework of Ullmark et al (1986) pointing at three types of governing rationalities:

- producers' perspective
- wage-workers' perspective, and
- perspective of democracy.

The producers' perspective points at the possibilities as a member of the organisation to be able to produce a product of quality and in resonance with your values. Some degree of autonomy and the mobilisation of one's skills are central elements in this perspective. The wage-workers' perspective relates foremost to a decent pay, codetermination, job security, health and safety and the like. The democratisation perspective aims at making it possible for employees to act collectively and strategically. Ullmark et al argue that workers uses these rationalities in developing interpretations in everyday work life including management's acts and intentions of change. Tension between these rationales creates ambiguity of intentions, which is a clear example of the conditions of possibility for management and production at the site. On the one hand the producers rationale can be activated and be a forceful mean of agile and flexible task solving. On the other hand this perspective can itself embody hindrances for new paradigms of producing and other perspectives can be mobilised in ways which are more or less in contradiction with the producers perspective.

Although ambiguity is an important aspect of culture, Alvesson (2001) and others point out that despite of this, groups and organisations must develop at least some degree of mutual understanding of how to deal with problems, which gives direction and makes cooperation possible. Even if culture does not produce clarity and consensus throughout an organisation, it can offer guidelines for coping with ambiguous meanings, giving clues on how to deal with tricky issues. Such bounded ambiguity may also be seen in quick switches between different social circumstances, legitimating various sets of ideas and meanings.

Multiple configuration

Where the dominant view among culture study scholars are integrationist, a few are differentiating, even fewer attempt to synthesise these approaches (Martin and Frost, 1996, Martin, 1992, 2001). Parker and Alvesson both try to offer a way of at least juxtaposing the three perspectives. Alvesson thus notes the differences in assumptions of scope of cultures, whether they are macro cultures, such as national or local such as groups. These cultures potentially overlap and interact. Parker suggests overlapping, subordinating, subordinated cultures (Parker 2000: 224). Alvesson introduces the multiple cultural configuration view (Alvesson, 1993:118): It assumes that organisations can be understood as shaping local versions of broader societal and locally developed cultural manifestations in a multitude of ways. People are to different degrees connected with organisation, suborganisational unit, profession, gender, class, ethnic group, nation, etc. Cultures overlap in an organisational setting, and are rarely tightly connected to the social structures of the organisation. The central argument for introducing the multiple configuration is to combine insights of the above mentioned approaches. It recognises the role of macro cultures, local cultures and possible integration and unity. The mixture and overlapping character is, however, a central observation.

ORGANISATIONAL CULTURES IN CONSTRUCTION

All building projects are temporary organisations, established to realise one of a kind-products. In principle this can mean that the partners are new in every new project. This could lead to entirely local and weakly underpinned cultures. Empirical studies show however that the "radical reconfiguration" of partners in practice might be much more limited because partners which have previously cooperated do it again and/or the embeddedness of the construction companies in small regions means that they reconfigure recurring partners (Kreiner 1976, By og boligministeriet 1999). These networks of recurring partners could then produce an organisational culture. Loosemore and Tan (2000) argue that actors in construction employ stereotypes of the other roles in the projects. In this way integrative culture could be produced on a sector level used a shared frame of meaning on how the different classical roles were to be filled out. In large scale building project one could moreover expect another dynamic for the organisational culture. The great cultures of the participating countries could come in play. This aspect is however not studied or discussed further here. Finally one could expect a culture production stemming from the crafts. These are traditionally organised in teams or gangs. These are quasi permanent over time and from one building project to another. The teams are strong work organisational units and could therefore be expected to produce organisational culture. The crafts are however in flux: specialisation and the tendency of the development of assembly skills especially among carpenters undermines the traditional crafts. Unions merge, potentially enabling restructuring of contracts and thereby setting new frames for culture and organisation. As we shall see below the teams are indeed strong cultural units and the flux is apparent but not decisive.

BUILDING APPARTMENTS – MAINTAINING CULTURES. THE SITE

The project concerns the construction of an apartment building in the Copenhagen area. The building contains 178 apartments, the budget is 18,5 million £. The organisation is composed of 52 contracts held by 28 different contractors. Below the focus is on three crafts teams and the site management.

The *prefabricated concrete team* has 14 members and a foreman. Five members of the team have worked together for 15 years and are between 55and 60 years, whereas the youngest four are between 24-26 years. There is one woman in the team. The division of labour within the team is relatively well defined.

The *mason's team* has 11 members and a foreman. The members have ages from 30 to 60. Eight are skilled mason whereas three are unskilled masonry workers. This also constitutes the division of labour between bricklaying and supporting the materials; bricks and mortar.

The *roof carpenters team* consists of five members and a foreman. Most of the members are closely related; three are relatives and one more has been apprentice with one of them. They all belong to the region where the carpenters firm originate (which in this case/on this site is remote).

The *site management team* consists of the project manager, three managers of contractors, an accounting manager, a quality manager, a trainee and a secretary. Four of the managers have cooperated on several projects over the last three years. The rest have never been cooperating before.

The integrative elements in the site culture

It is difficult to find the integrative elements in the everyday routines since those are marked by geographical distance among the teams working at the site. However certain acts and physical symbols underpin the development of the integrated culture. The structuring role of time, the prevalence of the producers perspective, the topping out ceremony, site coordination meetings and pinups i.e. photos of nude women in the site huts were the main elements found. The role of time, the pride of the produced and the pinups are elements unifying across the studied crafts team, but not the site management, whereas only the topping out ceremony actually gather participation from all teams including the site management. The site coordination meetings gather representatives from the contractors but not necessarily from the teams. As analysed elsewhere the site coordination meeting often take a symbolic turn, where the "decisions" taken mirrors day to day coordination already carried out (Kreiner 1976). The tight interpretations of time occur across the crafts teams but not with the site management. The craft teams meet in the morning before 6.30 a.m. and gather in the site hut. Similarly the breaks are taken literally on time. One wouldn't see anyone working past 3 p.m. and nobody commences working single-handedly. These assignment of meaning to time can be interpreted as a rigid balance between the wage workers perspective and the producer perspective. Several teams are paid by piece rate. The topping out ceremony encompass the gathering of all active members of the site organisations. Speeches are given, the participants are offered food and drinks and the ceremony did gather almost everyone at the site. As integrative element it should not be overestimated however, since it occurs once during a building project. And as we shall see the ceremony is not unambiguously integrative as event.

Visiting the Tribes: The differentiating elements among the site cultures

It is tempting to start discussing the differentiating elements by presenting an alternative account on the role of the topping out ceremony. In a way the ceremony also demonstrated the deep separation between teams and groups on the site. The members of the site organisation seated themselves according to which firm they came from. The carpenter's team even uses sweatshirts with logos of their enterprise physically separating them from the rests. The ceremony are not stronger than people sits uneasy during the speech of the architect and many leave early after the ceremony, which was placed on a Friday afternoon. The topping out ceremony is however a weak indicator for the differentiation. Visiting the teams reveals marked differences in cultures: The *prefabricated concrete team* is best characterised as a mute team. Its cooperation occurs with few verbal elements, one gets the impression that the routines are strongly embedded. They know what the others will do and what their own acts are. Verbal metaphors and myths are articulated mainly during the breaks. Narratives on major previous jobs many years back are an example of this. The foreman plays a role as model for the team. The tempo of the group is relaxed since the crane sets work cycles. This is expressed in a physical symbol by one of the members which permanently carries a cheroot in his mouth. A wage worker perspective seem to dominate, but not as clearly as in the masonry team. The *mason's team* are loudly shouting. The piece-rate induced tempo is high and maintained by a strong work companionship. However the team also has a marked hierarchy between skilled and unskilled masons. A myth on a skilled mason ordering an unskilled to unduly "over"pack a container underlines the importance of the hierarchy. The work is monotonous and repetitive, but the tempo is held high in common understanding of the importance of high pay (the wage worker perspective). Also the *roof carpenters team* has a strong work companionship and the members express joy about the product and the work. They work energetically and scrupulously, symbolically expressed by running up the stairs and by openly discussing solutions on occurred problems. They interact and communicate with other groups on the site. Also they carry shared myths on classical skilled carpenters work, especially expressed by a story on a job on restoring a monastery. For the *site management team* the focus is on making profit for the company. This motive guides many acts and is also mobilised in interpreting acts of other groups on the site. In doing this "being busy" is important and underlined by symbolic acts such as throwing the phone back in its holder

These patterns means that it on the site appears at least the studied four local cultures and probably many more in the other contractors teams. These cultures are characterised by internal shared meanings especially expressed in common myths on previous work done together and physical symbols but also symbolic acts. It is moreover possible that these cultures are crafts-cultures, which cut across sites or that they represent local firm-cultures, which will prevail across sites. The present study-s focus on a single site means that it cannot distinguish between great cultures and local cultures.

Ambiguity- several meanings can be referred to

Although the differentiation perspective clearly identify four local and distinct cultures, there are also ambiguities among them and across them. One example is gender and generation issues another the existence of individualistic acts and symbols within the teams. First the gender issue. Although the common culture on the site is clearly male dominated and underpinned with pinups and a relatively hard male rhetoric, members of the concrete element assembly team express concern for and care for the female apprentice in the team. This means they appreciate talking and acting in another way when the female colleague is around. Second the generation express themselves by drinking different things in the breaks. Finally at least two examples occur where members adopt individualistic symbols and acts, such as long hair, working harder etc.

Spots on a leopards skin- the multiple configuration

The analysis above have shown a pattern of at least four cultures presumably firm or professional cultures, which appears to be markedly different (the crafts and site management). They appear to feature geographic and social distance between each other despite their part in a common task and physical space. They thus appear as spots on a leopard's skin. As a crosscutting and much weaker common integrative culture we find references to time, pride over products and the ceremony of topping out. Finally there are ambiguity even within the local cultures.

DISCUSSION AND CONCLUSION

The most important result of the empirical analysis is the emphasis on several separated cultures, which is in sharp contrast with most culture studies as well as the implicit belief in most culture management prescriptions. Here one would find that a strong monolithic culture is attractive and typical. It is however hardly a surprise for the experienced site manager that the craft teams and the site management are that internally different.

Maybe a more surprising result, given Loosemore and Tans work, is the *absence of stereotypes* or other kinds of references to conflictual relations between the actors. The tribes do not seem to need stereotypes or demonising of their neighbours.

The study shows very clear examples of how strong the producers' perspective can be. Especially the roof-carpenters, but also the site management show this. Moreover the roof carpenter exhibit praxis of coordinating with other groups on the site. On the other hand the two other craft team are less clear in their priority of producing. The masonry-s works are impacted heavily by their piece-rate and the assembly team has few elements in its work it can influence. Releasing a further productive potential in these groups also needs underpinning by changing these frame-setting structures.

The implication, for site management, of the possibility of a multiple configuration of cultures at the site is to address this as a necessary coexistence of multiple cultures, rather than only attempting to build and integrate a common culture. The means for integrating cultures are not strong enough in an average construction job. The temporary character of the site-organisation contrasts to the long-term relationships within the teams. The management approach should rather be to understand and allow the different cultures to flourish in a way that make them productive. Using codetermination and multiskilling is however in a longer perspective a way to develop new crafts-profiles and thereby a stronger integrative element in the cultures. The coexistence between cultures will then be characterised as a more organic symbiosis between crafts.

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Informal Construction Workforce Phenomena

Isabella Njeri Wachira

ABSTRACT

Since the early 1970's a new phenomena known as informal construction sector has been growing in the construction industries in the developing countries particularly in and around urban areas. The essence of the concept informal is unregulated and it is mainly used to represent workforce which;

- *Mostly self employed*
- *Has no regulation or protection from the law*
- *Is employed in unregulated and competitive markets*
- *Use simple technology mainly labour intensive*
- *Skills acquired outside of the formal school system*

The informal construction sector mainly comprises of unregistered and unprotected individuals and small enterprises that supply labour and contribute in various other ways to the output of construction.

The decline of economic growth in the late 1980's and 90's has seen the government's, (which was formally the biggest and the most influential construction client) influence in the construction sector wane. This has consequently led to the decline of the formal construction sector and the phenomenal growth of the informal construction sector. The informal construction sector is currently the biggest employer in the Kenyan construction industry employing up to 75% (58,900 persons) of all the labour-force in construction. The lack of regulation and recognition of the informal construction sector has limited the potential of this sector in terms of advancement of skills, access to capital and protection from exploitation.

The informal construction sector has over the last ten years emerged to be a major player in the construction industry but little has been done to understand this sector. This paper seeks to shed some light on the informal construction sector with particular emphasis on the workforce

Keywords: informal construction, Kenya, workforce.

INTRODUCTION

Informal sector is an important part of the overall economy in most developing nations and in Kenya, it contributes upto 13.80% of the Gross Domestic product [1]. It can thus not be ignored in the endeavour to achieve national goals particularly employment creation, poverty alleviation and balanced development.

The informal sector in Kenya is growing very fast and in 1999, it composed of 1,289,012 firms employing up to 2.3 million persons. Most of these firms are in Trade and Services sector with construction firms accounting for 22,087 that is 1.7% of all the firms. The main features of the informal sector are [2]; Ease of entry; Small scale activity/self employment; Labour intensive technologies; Absorb large number of the unemployed but can not give any guarantee of long term jobs; Low level of organization with little access to organized markets, formal credit, and education/training; Cheap provision of goods and services; Low productivity and income; Non compliance with official and administrative requirements; Do not pay taxes mainly because they are not registered

All the above features combine to create an informal sector that is mainly unregulated and unprotected by law, working in an environment of high competition. Most of the workforce reported in the survey [2] that they joined the informal sector mainly because;

- They had no alternative i.e. they were unemployed (white collar jobs) for a long time
- Better income in the informal sector i.e. wages are unregulated and usually depend on the ability of the individual to negotiate for better terms
- Prefer self employment - their has been a wave of focus on self employment as a measure of ones achievement as a person

Informal sector firms are highly flexible i.e., they can quickly be altered to meet any specific demands in the market without much ado, and do not thus fit into the formal/legal system which does not allow or encourage such flexibility [1].

The informal sector is to be found in many developing countries. In Peru, it has been so successful that it is viewed as an impressive revolution [3]. Informal activities are illegal but not criminal taking place in absence of legal protection and guarantee's i.e. it composes of underground activities that have legal ends but employ illicit means. In Peru the informal sector accounts for 38% of GDP and 60% of all man-hours worked. The informal sector has low productivity because; their informal contracts are not legally enforceable; they can't take insurance against risk; they can't acquire secure property right.

Informal construction sector in Peru as in other developing countries, is vibrant and has alot of economic, social and political importance in that it helps the less privileged own something thus giving them a sense of responsibility, struggle and political challenge

INFORMAL CONSTRUCTION SECTOR

Table one below shows the Kenyan construction informal sector contribution to the economy. Clearly from the data it is obvious that in the last five years the private/informal sector has been a significant contributor to both residential and non-residential construction in the country and it is the most significant employer. With the advent of the Structural adjustment era beginning in the early 1980's, the government drastically cut its development expenditure and construction was the main culprit of these austerity measures, leading to a marked decline of the government influence/participation in the construction industry [4].

The private sector was then left, as the leader in construction in Kenya with most buildings being constructed by individuals whose access to capital funding is at best erratic and unpredictable. This then led to the emergency of a vibrant informal sector, which was able to adapt to the unpredictable needs of these clients. Most of the buildings in the private sector are built by the informal sector in middle to low income neighbourhoods in urban and peri-urban areas. The informal construction-housing sector is the fastest growing construction area in these hard economic times where the owners, as is the case in Mexico, start with simple structures to provide basic shelter and then improve the structure as time and finance permits [5]. Most of these buildings/houses are constructed on

Table 1 Contribution Of Informal Construction Sector

YEAR	BREAKDOWN OF CONSTRUCTION OUTPUT K£M		INFORMAL CONSTRUCTION CONTRIBUTION TO GDP %	EMPLOYMENT IN INFORMAL CONSTRUCTION SECTOR
	RESIDENTIAL	NON RESIDENTIAL		
1995	46.03	20.18	1.7	31,600
1996	51.64	21.03	1.6	36,000
1997	54.24	26.27	1.6	40,700
1998	55.10	21.40	1.6	51,200

1999	44.51	19.24	1.6	58,900

land that has no clear titles, no provision for of urban infrastructure e.g. water, sewerage, electricity or paved roads, no land is set aside for public uses such as schools, parks or transportation corridors which in turn limit the owners access to loans (banks are unwilling to give loans for construction on land without titles because the property can not act as collateral security). Mexico has also had the same experience where significant demand for housing particular by low income households has led to the emergence of a vibrant informal sector which the government generally tolerates since it is unable to provide adequate housing [5].

The informal construction sector is composed of many firms dealing with on site construction, supply of materials, fabrication of elements e.g. steel casement windows, doors, hardware outlets supplying materials and tools. This paper will mainly deal with workforce in the on site construction informal construction sector e.g. masons, carpenters, steel fixers, concretors, electricians, plumbers, painters, joiners, tile (and other finishes) layers and unskilled labourers.

Informal sector construction differs significantly with the traditional construction procurement methods that are characterised by;

- A client that has access to capital funds and is able to pay the builder on demand
- A team of professionals including an Architect, a Quantity Surveyor and Engineers to oversee the design and construction of the project and act as an intermediary between the client and the builder
- A contractor who is responsible for the construction and completion of the project within specified quality, time and cost
- A formal contract agreement that spells out the responsibilities and legal obligations of each party which is enforceable in law.
- The informal sector represents a different kind of construction procurement characterised by [6];
- Clients whose access to capital funds for the project are highly unpredictable and erratic which in turn means that construction time is unknown/unimportant as the projects usually experiences a lot of stops and restarts depending on the availability of funds i.e., flow of funds is the main time determinant e.g., a project for the construction of a three-bedroomed house may take up to five years

- The project may not be supervised by any professional. In some cases the design may be done by a professional or by a draughtsman, but when it comes to construction they are not consulted since most clients deem their charges to be exorbitant. The fact that these houses do not go through the rigors of approval by the local authorities make this possible and in most cases the buildings are designed as the work proceeds.

- The owner of the building will in most cases buy the materials for construction at the various stages and hires one tradesman to act as the foreman to oversee the construction. In other projects the owner will hire tradesmen and unskilled workers on daily basis depending on the current work on the project e.g. if walling stage he hires masons and unskilled labour for as many days as is required to finish the work item or for as long as he is able to buy materials to keep the workforce engaged for a full day. The owner has no say on the usage/wastage of the materials

- Quality assurance is done by the owner, his family and friends, the gauge being comparison with other buildings in the surrounding i.e. it is not unusual to visit other developments to give the tradesman an idea of the quality expected by the owner. Cost control is left to the owner who purchases the materials and negotiates daily wages with the workforce

- Workforce lacks any significant degree of social protection mainly in terms of enforcements of minimum wages and other terms of employment, health and safety regulations, and workmen compensation. This of because the workforce is not covered under the Trade Disputes Act [7], Factories Act [8] or the Workmen's Compensation Act [9] which regulates the said issues

- There are no formal contract agreements and any legal queries are born by the owner with no recourse to the workmen. The owner bears all the risks

- Most buildings are not approved by the local authorities or any other authority and are constructed with no consideration of the by-laws, have no insurance covers or any other legal requirement

INFORMAL CONSTRUCTION WORKFORCE

The informal construction sector is expanding mainly because it responds to the needs of certain construction sector clients which has been long ignored by the traditional/formal sector. The informal construction workforce is made up of many persons who join the construction industry as a last resort when all else has failed and they exit the industry in the first possible opportunity. Take an example of Odera. He sat for his secondary school exams in 1985 but did not perform well enough to join any institution of higher learning. After 'tarmacking' (local word for looking for white-collar employment by walking up and down the tarmac roads until they wear off your shoes) for eight years his family prevailed on him to join his uncle who is a plumber. Odera learned on the job and has become an accomplished plumber now working on his own. He however feels that his job is unrewarding in terms of pay and recognition as exemplified by the fact that he lives in a one roomed shack at the Kibera Slums, Nairobi. Odera does not miss a chance to remind his family and friends to work hard in their studies so that they do not end up like him. Clearly, there is no pride in this kind of work and one would rather not be identified with it or be a role model for future entrants [10]. This is the profile of most workers in informal construction sector. The Kenyan informal construction sector is characterised by many informally organised and unregulated workforce characterised by the following; [11]

1. Mostly self employed - most of the workforce in the informal construction sector are self-employed meaning they do not have any employment contracts with any employer/firm. They move around in areas where construction is prevalent and are hired by the owners or the foremen in charge of the construction on casual basis. Employment in a particular site may last for one or more days depending on the pace of the work, availability of materials and funding

2. No regulation or protection from the law - most workforce in the informal sector do not have any employment contracts and are thus not covered by the Employment Act Cap 226 [12] neither are they members of the existing Trade unions – the Trade Union act requires that it members have employment contracts [13]. Informal construction workers are therefore not covered by the Employers and Trade Union agreement which every year spells out issues of concern to workers, e.g. wages, working hours, allowances, terms of termination/redundancy, retirement, tools allowances and protective clothing [14]. This means that these workers do not have any recourse or protection from exploitation in law e.g. minimum wage, terms/conditions of work or compensation due to accidents on the site, but on the same token it means that they are not regulated by the existing laws. Safety and

health issues are thus largely ignored with most sites not having even sanitation facilities like toilets

3. Employed in unregulated and competitive markets - the market in which informal workers operate is unstructured and unregulated. Employment is thus based on the relationship between the workers and the owner/foreman mainly governed by the reputation of the particular worker in the neighbourhood. Due to lack of regulation the market in informal construction is highly competitive often leading to situations where workers are willing to accept less that the legal minimum wage to establish a relationship with a client that is likely to be a source of work in the future. Wages here depend on experience, skills, level of production, agreement or relationship with employer/foreman and ability to negotiate/bargain

4. Use simple technology mainly labour intensive - the technology used in informal construction is labour intensive with very little use of plant and equipment. Use of these labour intensive methods and rudimentary tools mean that the energy input in any task is relatively high and thus most of this workforce is in the 16 to 40 years age bracket [15] - it is definitely not for the weak and the workers have acquire a reputation of hardworking, dirty, rough, hard 'eating' group. Labour intensive technology is used because construction plant and equipment is relatively expensive and out of reach for these workers most of who earn just enough for their daily needs. In any case, most of these workers have no training in the use of heavy construction machinery and equipment. Owners will sometimes hire basic machinery mainly concrete mixers and poker vibrators but this is rare. In view of the massive unemployment currently in the country, labour intensive methods of construction are not only deemed economical but also beneficial.

5. Skills are acquired outside the formal school system - a survey [6] of the workers in the construction sector shows that more than 90% of them acquired their skill outside formal learning institutions. In most informal construction sites new entrants are taken on as apprentices attached to experienced tradesmen in the skill area they wish to acquire. The new entrants start of as unskilled people and over time and after working closely with the skilled workmen, their responsibility over the work items increases until they are deemed to have acquired the requisite skills. They can they proceed to take up whole work items on their own and gain experience and reputation. This method is deemed to be more cost effective, respects traditional values and provides the better preparation for self-employment.

New skills and technology are often transferred to the informal sector from the formal sector through the employment of the informal sector workforce in formal construction [17]. In between jobs in the informal sector the workforce are hired by contractors in the formal construction sector on a labour only basis for varying periods of time. During such times, the informal workforce is exposed to new materials, skills and technology, which are current in the formal sector and when they go back to the informal sector, they are able to advise potential clients accordingly. The formal sector is able to use new materials, skills and technology mainly because they have professionals who are in touch with the changing technology in the construction world supervising the construction and they pass these new technology to the formal contractors/workers. Clients in the formal sector are more open and can afford to test new technologies, materials and skills when compared to clients in the informal industry who usually work on shoestring budgets and thus prefer to use conservative time-tested methods that are unlikely to generate any significant errors. Formal sector employment thus acts as a fertile training ground for informal sector workforce and this exchange should be encouraged as a means of transferring appropriate technology to the informal construction sector.

The government in an effort to encourage the training of labour in various trades formulated the Industrial Training Act [18] which issued a legal notice No. 237 requiring all construction projects worth more than Kshs. 50,000.00 (US$641) to pay 0.25% of the contract sum as a training levy. The said monies are then used in the training of various workers in the construction industry. The informal construction sector does not pay such monies mainly because the projects are not registered or have formal contract agreements, and does not benefit from this kind of formalised training. Workers in the informal sector thus miss out on skill development from this fund. Since as noted above the informal sector is the biggest employer in the construction industry, the fact that they have no access to these funds means that they are minimally utilised - currently has a credit in excess of US$ 853,544 [19] - despite the dire need of training in the informal construction sector. This needs to be addressed for the benefit of the whole industry.

High exposure to occupational health hazards - there are many forms of occupational hazards in the informal construction sector including [16];Physical - noise, heat, dust; Chemical - solvents, acids, resins; Mechanical - cutting, grinding, vehicles; Ergonomic - poor working platforms and positions; Biological - injury; Poor access to clean workplaces, toilets and water. These hazards are exaggerated in the informal sector due to the pressure to generate income 'at whatever cost' because low level of capitalisation means use of primitive tools and techniques and workers tend to take risky shortcuts in production; poor regulation/monitoring of labour/health/safety laws - the government does not have the resources to monitor and poor access to information about hazards their effects and control - most of the workers are unaware of the risks until serious accidents occur and even then they accept it as fate.

Most of the workforce in the informal sector have very little access to health facilities so most of these hazards are not identified or documented i.e. there extent and effect are thus unknown and not addressed. Survey [6] however indicates that they are subjected to these hazards and sometimes they have serious accidents on site, which lead to death loss of limbs, impairment to eyesight and hearing, etc. The fact that they do not have any form of insurance or workmen compensation means that most of the victims just leave the industry and the whole medical burden is borne by their families.

These are the main characteristic of the informal construction sector workforce.

Documented Cases Of The Effects Of Lack Of Regulation In The Informal Construction Sector

Most of the construction work done by the informal construction workforce goes on unnoticed as the projects are completed without any hitches. Occasionally however, there are documented cases of the effects of lack of regulation of the informal construction sector in the local dailies. These usually happens when there are serious accidents on site mainly caused by poor work processes and exposure of the workforce to hazards outline above e.g. 22nd September, 1997 a building collapsed killing two people and injuring others in Eastleigh, Nairobi - the building was under construction when the third floor which was constructed of concrete collapsed bring the whole building down. Investigations revealed that the construction had no proper working or structural drawings and it was not sanctioned by the local authorities. The informal workforce on the site compromised on the materials quantities and preparation in a bid to save the developer money [21]; 16th March, 1999 a building in Nairobi golf course collapsed because it was constructed without proper columns although it had a first floor. Like the one above it was not sanctioned by the local authorities but fortunately for the residents, it collapsed at night and nobody was injured [21]; and 8th November 2000, a six-storey building in Tena Estate collapsed due to overall poor construction methods and materials. The building was as above and it led to the death of several workmen and passer-by's [21].

Government And /Or Private Regulations And Interventions

There are many hindrances to the efficient performance of the informal construction sector, which require to be addressed. While the government might take the lead to assist this sector, the needs/tasks are too daunting for any one group and other organisations with interest in the informal sector can be encouraged to lend a hand e.g. ILO, Habitat, Micro-finance organisations, universities and Non

Governmental Organisations. Research has shown that the government may not be the best suited to meet some of the challenges here e.g. training, due to excessive bureaucracy, but areas like changes in the legal set-ups are clearly in the governments domain. Interventions necessary to assist the informal construction workers include among others;

1. Change the Employment act to suit the flexibility required by the workforce - this is a workforce that rarely have any employment contract but this should not mean that they should not be accorded the same protection in law as other formal workers e.g. workmen compensation e.g. fair wages and workmen compensation

2. Change the Industrial Training Act to recognise/sanction on job training - currently the Industrial training act only recognises and acreditates graduates/tradesmen of formal school system and has made no effort to grade and register those in the informal sector who are trained via the apprenticeship system even where they have demonstrated their competence. Training levy can be used to formulate appropriate training programs for this workforce

3. Markets and marketing information - one of the weaknesses of the informal sector is its inability to use appropriate technology leading to a narrow product range and hence cut throat competition and market congestion, poor quality products, lack of access to public sector markets and lack of substantial sub-contracts from the large firms. Those supporting the sector can thus assist the workmen by introducing appropriate techniques and circulating information on the needs in the market. Through the large public sector projects the government can encourage/motivate large construction firms to sublet part of their works to the informal sector - this will not only improve their skills and technology but will also widen their job market

4. Training - in the 1999 Micro and Small Businesses Survey [2], informal construction workers identified training as their most pressing need. This training they suggested should emphasis management skills so as to assist them is developing their entrepreneurial skills (business management) and training on technical aspects of their work i.e. learning the new skills, materials and technology in the construction market. Most felt that this would increase their job pool/markets by allowing them to undertake bigger and more complex projects while at the same time advising their clients on the said issues. For the training to be successful there is a need to establish the needs of this group and the means of communication - most of them have low level of education thus English which is used in most formal training programmes may not

be the best. Trainers must also appreciate that the demands of living can not allow these informal construction workers time off to pursue training and thus these programs must be designed such that they cause as little disruption as possible to the work e.g. by carrying out the training on the job as much as practical.

Training can also be used to transfer and develop skills in this sector with the aim of not only increasing productivity but also incomes and thus reducing poverty. It can introduce new technologies and local materials and must aim foremost at upgrading skills of those already in the sector who will then transfer the skills to new entrants via apprenticeship. As these new skills/techniques are introduced funds must be availed to assist these workforce purchase more efficient tools of trade [20] otherwise the training will not produce any significant results.

Training in the informal construction sector will require the use of innovative methods so that the language, terminology and attitudes is acceptable and understandable to this group who have little formal education.

5. Organisation - the informal sector workforce needs to be organised so as to lobby for issues that concern them (e.g. insurance, training, regulation) and so that they can take advantage of exchange of experiences and improvement of skills through training. Such organisations will help the informal construction workforce to negotiate with existing bodies like the Federation of Kenyan Employers and Trade Unions, so that they are covered by the wage and condition of work regulations - this will minimise their exploitation. Dealing with the informal sector workforce as a group will make any programs economically viable and will have more chances of success

6. Reduce the cost of legality - the informal sector shuns legal requirement mainly because of the high cost in terms of time and information necessary to comply with it - the transaction costs or costs of compliance are greater than benefits thereof. The government should take steps to streamline its institution to minimise not only the cost of compliance but also the time required thus encouraging many in the informal construction sector to comply with requisite legal requirements. This will make control and regulation of the informal sector easier

7. Occupational health issues - devise means of enforcement of occupational health laws and reduce exposure of the workmen by encouraging the informal sector workforce to use work processes that

reduce occupational hazards while improving working environments and output e.g. by using protective clothing and educating workers on ways of minimising accidents on site. This process must begin by first educating the workforce on the existing hazards and means of controlling them while at the same time convincing them that it is for their benefit

8. Contract agreement - organisations should take the initiative to formulate simple contract agreement for the informal sector to ensure that the workforce has some form of protection and that risks involved in the works are equitably shared - such contract should be in a language that is understandable by all

These are some of the interventions necessary to improve the informal construction sector workforce. Their implementation must be long term and must focus at achieving tangible benefits to the workman and consequently the industry at large.

CONCLUSION

The informal construction sector is a significant part of the construction industry in the developing countries and any changes in the construction sector can not afford to ignore it. Although it has some weaknesses, its role in the economy is significant enough to warrant focus on means and ways of minimising or addressing these weaknesses for the overall development and progress of the construction industry.

The most significant form of intervention are; Formulation of flexible forms of regulation that will take into account the characteristics of this sector; Organisation of the workforce so that they can easily lobby and deal with issues of concern to them; Training to improve skills and technology with the aim of improving the efficiency of the sector. These interventions will enhance the role of the informal sector and help achieve the noble goals of not only employment creation but also poverty reduction.

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DIRTY CONSTRUCTION WORKERS: WHO YOU LOOKING AT BUDDY?

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ABSTRACT

The public perception of the United Kingdom building (construction) industry and of the workers who are employed in it is often associated with negative stereotypical attitudes. Workers (and thus the industry) are characterised by images of dirt, unsafe working practices, macho and sexist behaviour and unsatisfactory workmanship standards. Such perceptions are known to have damaged the image of the construction industry and may have led to large sections of the construction workforce being stigmatised. This in turn is known to have persuaded many youngsters that a career in the construction trades (joiner, bricklayer, plumber etc) is not for them. However, very little empirical knowledge (other than a few notable studies conducted in the USA by the likes of Silver 1982, Riemer 1979, Applebaum 1981) can be found regarding the perceptions which the craft workforce have of their occupation role in society. This paper examines the perceptions which craftworkers have of their occupational role. This work is discussed within the context of a current UK Government department (Department of Trade and Industry) initiative known as 'Respect for People.' This initiative seeks to encourage the construction industry to improve the health, safety and welfare facilities on projects and thus mitigate some of the 'dirtiness 'attached to construction work life. It suggests a research programme to fill in the gaps of knowledge in the perceptions of how tradespeople view their work, its environment and self esteem associated with their jobs.

INTRODUCTION

The construction industry relies on a vast array of specialised building craftsmen / women to fabricate and assemble a multitude of building materials / components. The knowledge and skills used by these craftspeople has developed along with the innovations in the building industry. From mud to concrete, steel to plastic, and timber to resins. One might suggest that given the current agenda for sustainability, this situation might have turned 'full circle.' However, perceptions held by people today of these craft workers is, it is argued, much changed from yesteryear. The 'artisans' for example are no longer established pillars of the community (butcher, baker and candlestick maker) and it is unusual indeed to even hear of reference to such terminology. John Ruskin (1867) observed that it would "be part of my scheme of physical education that every youth in the state - from the Kings' son downwards should learn to do something finely and thoroughly with his hand; so as to let him know what touch meant and what craftsmanship meant. Let him once learn to take a straight shaving off a plank, or draw a fine curve without faltering or lay a brick level in its mortar and he has learned a multitude of other matters which no lips of man could ever teach him". Nowadays, we are more likely to refer to 'cowboy' builders than to craftsmen.

The current desire for improvement in the construction process through 'drivers' such as the 1998 'Rethinking Construction' (known as the Egan report) report and enacted through the Movement for Innovation (M4I) programme call for increased standardisation and prefabrication. This would tend to suggest a change in the process of fabricating / assembling / jointing building components, be they on site, or in factory conditions. Such change must surely lead to opportunities for evaluating the skills required of building craftworkers. Indeed, given the shortage of school-leavers entering the construction industry, a significant increase in the use of automated building processes may be the preferred option. However, the need for traditional occupations (joiner, electrician, plumber, bricklayer etc) is unlikely disappear overnight, and as such we must find methods of marketing such occupations in an attractive manner.

The construction industry has itself made headway with this problem. The M4I 'Respect for People' initiative, through its Site Welfare Checklist for example, calls for clients / contractors to provide much improved welfare facilities on site, thereby reducing the 'dirtiness' of construction's image. Prior to this initiative, the more enlightened clients and contractors understood the importance of such issues. For example, the welfare facilities at the new SmithKline Beecham headquarters site were described as the 'A4 Hilton' (Contract Journal 1999b). However, these projects are the ‘exception’ rather than ‘the rule’. A survey conducted by the Contract Journal (1999a) found that many of the contractors who attended the first ‘Egan’ conference were not providing workers with clothing, good toilet facilities or showers. On a lighter note, it can be seen that welfare facilities on site often have a dual purpose. The Cameron (1967) report of the inquiry into trade disputes on two London construction sites found that the canteen arrangements on one of the sites doubled as a licensed betting shop! The report concludes that such a facility appeared to provide an unnecessary attraction.

INDUSTRY IMAGE

The UK construction industry has for many years suffered from an 'image' problem. Media depictions of construction in general and contractors in particular perpetuate the impression of an industry populated by small-time crooks and 'cowboys' out for 'a fast buck' (Building, 1998). Moreover, building workers all too often provide the clowns in the situation comedies on television (Centre for Strategic Studies in Construction, 1989). Baldry (1997) is however partly correct when he argues that such negative images are often a result of misinformation and mythology. However, it surely cannot be contested that such perceptions make it difficult to recruit skilled tradesmen / women. Sixteen year old school-leavers, traditionally the source of apprentices for the industry, generally view it as dangerous and dirty with limited prospects (CITB, 1998). Industry practitioners also express such views. James Armstrong, chairman of Laing's construction arm suggests that the industry's recruitment problem is a result of poor continuity of employment, low investment in training, poor pay, poor health and safety, poor site conditions and low esteem (Contract Journal 2000a).

CULTURE OF CONSTRUCTION WORKERS

Given the significant problems associated with perceptions of the construction industry, it might be expected that there is a substantial literature base concerning construction industry culture. Sadly, however, only a relatively small number of studies dealing with construction craft workers exist. Indeed as Silver (1982) observes, the organization of craft production and the quality of work for those in craft occupations are poorly understood. However, there are three significant textbooks which provide rich insights into the life of construction craft workers, albeit from an American perspective. Riemer (1979) a time served electrician and professional sociologist and Applebaum (1981) a construction project manager provide ethnographic accounts of construction workers on construction sites. Reimer explores deviant behaviour and discusses such issues as drinking, girl-watching, stealing and loafing, while Applebaum argues that the traditional work ethic is still strong in construction. He suggests that this is demonstrated by workers; getting to work on time; following instructions and orders; co-operating with other crafts; having pride in workmanship; being honest about ones work and being willing to perform difficult and dangerous jobs. Dr. Silver (1986) - a wallpaper hanger by trade - explores the concept of alienation in the building trades and relates this to wider construction issues such as local market conditions, employers' demands and trade union activity.

Additional literature contributing to this the body of knowledge includes Davis (1948) who interviewed 400 British operatives and detailed their views on their jobs, working conditions and home life. Participant observation has also been used by the likes of Feigelman (1974) who explored topics such as voyeurism (girl watching) among the various building trades. LeMasters (1975) also used this technique to examine the life of 'blue-collar aristocrats' (building workers). This piece of research differs from the other aforementioned studies as LeMasters assumed the role of a patron in a tavern frequented by construction workers. LeMasters visited the tavern frequently and spent time drinking and playing pool while mentally recording (conversations recorded on to paper after returning home from tavern) discussions on topics such as marriage, work, drinking and politics.

The use of pubs (drinking houses) as a meeting place for construction workers is of course well established. Leeson (1979) refers to inns and pubs as the 'craftsman's lighthouse' and discusses the use of such establishments by early trade societies in the 19th century. Just as they were then, inns and pubs continue to be used as informal labour exchanges where trades can get information on jobs going and the signage above the door reflecting which trade frequented the establishment –Bricklayers Arms. Leeson notes that the second purpose of these establishments was to feed and bed those artisans whom were 'tramping' (tramp or journeyman) in search of work. Frequenting such establishments naturally has implications for the industry. Gerber and Yacoubian (2001) cite a study undertaken by the US Department of Health and Human studies that revealed that in 1997 the US construction industry had a higher percentage of illicit alcohol and other drug users than any other occupational category. In the UK, anecdotal evidence suggests that ecstasy, cannabis and cocaine are being used and sold on sites, with one report suggesting that site workers had been using the canteen microwave to heat up hashish before cutting for distribution (Building 2001c).

SOCIAL STIGMA

The social stigma inherited by those employed in the building industry can be considered a result of both the industry image and the negative perceptions attributed to occupational prestige. This is not to say that construction does not have a proud history of builders, engineers and 'navvies' but that to be 'a builder' in the 21st century means coping with negative stereotypical perceptions of such work. Building (1998) for example asks 'Why TV never takes us seriously' (construction industry). It is perhaps ironic then that the BBC's children's cartoon character 'Bob the Builder' is used widely as a positive role model during both the 1999 and 2000 National Construction Week (Building 2000a). However, scathing criticism of builders such as Bob also emanates from within the construction industry. For example, Robin Holt of Bath University comments on top end suppliers in the construction as 'two blokes with a rottweiler and a white van!' (Construction News 2000a). Operatives themselves also express such views. Steel fixer, Eddy Duffy comments that the 'average building worker is right-wing, racist and sexist, moreover, the management don't like women on site either' (Construction News 1999b). One might suggest that such comments are only anecdotal. However, in 1995 the then Chartered Institute of Building President, Michael Romans, commented that UK construction actively encourages its 'sexist, racist and homophobic image' (New Builder 1995). To compound such accusations, Contract Journal (1998a) reports that discrimination in the industry is also evident through ‘ageism’. Bricklayers are said to be particularly affected, although it is recognised that formwork and shuttering specialists tend to have a big core of older and specialist workers. Such discrimination is naturally worrying, particularly given that recent DETR figures highlight an industry populated by an ageing workforce, and one which suffers from a dearth of women and ethnic minorities (Construction News 2000b).

Reference can also be made to constructions 'macho' culture and its associated behavioural traits, which do perhaps emphasise such 'toughness'. Threat of violent behaviour for example and actual physical violence, although rare, do occur within construction. Incitement for violence and criminal activities (theft and sabotage of completed work) have been recommended by so called 'militant' groups as a solution to late payment of wages to operatives (Contract Journal 1998b). Riemer (1979) also comments on a related aspect of site behaviour. That of 'wolf whistling' at women passing by building sites. He argues that operatives indulge in such behaviour because society expects them to, and therefore completes the circle in stigmatising their role in society. However, the Construction Industry Board (CIB) has outlawed such behaviour in the UK. Their 'Considerate Constructors Scheme' includes a code of conduct which limits amorous attentions to 'admiring glances' (Edinburgh Evening News 1997).

OCCUPATIONAL STIGMA

LeMasters (1975) tavern research revealed that construction workers were ‘well’ satisfied with their position in American society. Riemer’s (1982) study concurs with this view when he suggests that tradesworkers are a distinctly proud class of workers who are well satisfied with their occupation. This is an interesting observation, particularly given Riemer's former life as an electrician. Rowings et al (1996) for example were surprised to find that, from a selected group of trades-people, electricians were in a low-pride category which also included plasterers. In addition this study found that less-educated respondents were more likely to be highly satisfied with construction work and are thus more likely to consider a career in construction. Rowing et al's claim that this reinforces the image issue of the poorly educated dominating the construction craft-force.

Melvin (1979) provides a useful summary of several studies used to analyse occupational prestige and acknowledges the view expressed by Roe (1925) that social status is more dependent upon occupation than upon any other single factor. Melvin's study included trade occupations (electrician, carpenter, plumber) with results from the USA, England and Japan. The combination of different research results shows that the prestige ranking for these trades is that of electrician, carpenter plumber (USA); carpenter, plumber (England) with the Japanese study only ranking carpenters, albeit relatively highly (most likely due to Japans long history of wood carving). The concept of occupational prestige is particularly important given that Construction News (2000a) suggests that site workers in the future will perform jobs with a vastly higher status attached to them. However, such claims were also made in the late 1960's in relation to the burgeoning use of prefabricated building components. The International Labour Office (1968) argued that construction workers employed within prefabrication plants, and thus experiencing both advanced technological change and increased welfare facilities (as compared to construction sites) would result in workers having a higher personal self-esteem and occupational status. Moreover, it was envisaged that such conditions would present a more favourable image of construction and have a correspondingly favourable effect on recruitment to the construction industry! This is of course pertinent given that Egan's 1998 report calls for an increased use of standardised and prefabricated building components.

Construction craftwork is recognised as an occupation that involves workers being exposed to dangerous, dirty and noisy conditions. Riemer (1979) notes that during the 'roughing' phase of building projects workers become 'locked in' to a setting that is rough, dirty and noisy. Applebaum (1981) asks that such blue-collar workers be given recognition for all the dirty, heavy, smelly and uncomfortable jobs that many people would not do themselves. Ashforth and Kreiner (1999) argue that such recognition is in fact internalised by 'dirty workers' and that the stigma of dirty work fosters development of a strong occupational culture. Their review of research suggested that dirty workers do not tend to suffer from low occupational esteem. Appropriate to construction is the reference they make to occupational ideologies- 'we perform dirty work because we're tough, not because we have limited options.' Indeed LeMasters (1975) also contributes to such a view by observing that craftworkers know they have done a 'day's work' because their clothes and bodies (dirt and fatigue) testify to the fact. Moreover, he suggests that these 'blue-collar' aristocrats feel they are earning an 'honest living' because they work with their hands. This 'honourable' perspective is also prevalent in Japan's construction industry. Levy (1990) for example, examined the Japanese construction industry, from an American perspective, and refers to the promotional work undertaken by the Japanese federation of construction unions (Zenkensoren).

This federation prints promotional literature (flyers) which is sent to the wives of carpenters telling them that their husbands are performing a noble and much needed trade. The purpose of such communications being to make the wives proud that their spouse is a carpenter. The contrast between Japans construction industry culture and the UK's is further contrasted by Bennett et al (1987) when they refer to the discipline and regularity of site workforce behaviour. One would however question whether the practice of, pre-work, 8.00 am bending and stretching exercises for all site personnel would be accepted by the UK's early morning 'canteen culture' operatives.

NEW SKILLS AND TRAINING

Two reports published recently suggest the need for new skills in construction. Hamer (1999) suggests that new career opportunities will emerge in computer programming and production, assembly and quality control. Additionally, on-site workers and those in pre-assembly factories will need both their traditional craft and new technological skills. The second round of the government's Foresight programme has also spawned a new report on construction. 'Building Our Future' (2000) recognises that new technology will require new skills for the site workforce. In addition it is envisaged that the use of site-robotics and off-site prefabrication will mean fewer people on site and a reduction in accidents.

Given that new skills will be required from the future construction workforce, it is disappointing that the current craft-workers are often seen as contributing little knowledge to the construction process. Lipton (2000) for example argues that clients rarely consult specialists such as bricklayers and carpenters and do not therefore benefit from their experience. He calls for a return to 'traditional values, and to get craftsmen back on site'. However, even when craft-worker participation could benefit individual projects, it would appear that this is also ignored. Blackman (2000) notes that on several M41 'Demonstration Projects' site workers were blissfully unaware that the workforce was involved in such an initiative. Blackman, a general secretary of the Transport and general Workers Union (TGWU) suggests that the casualisation of the workforce has led to this a lack of involvement and that such a culture must change if the M4I wish to improve the industry's image.

MUCK AND BRASS: TO EARN A DAY'S CRUST!

Given that many teenagers have perceptions of craftwork being 'low paid work' it is perhaps necessary to briefly examine the role of the current and past economic climate. The boom to bust construction economy has much to answer for in encouraging such perceptions amongst teenagers. However, current skill shortages throughout the UK (and Ireland) have resulted in many trades being paid £100-150 per day or around £20 per hour (Building 2001a) Such rates are far in excess of the nationally agreed pay scales negotiated by construction craft unions. However, such a position is interesting given that construction union UCATT are reported to be considering abandoning discussions on hourly pay rates in favour of a minimum starting salary of £15 000 to £16 000 per year (Construction news 1999a). The offer of such salaries may indeed be encouraging to prospective apprentices (albeit at the end of their apprenticeship) but the current weekly pay rates for 16 year old apprentices continue to offer no encouragement to enter the industry. For example, the chairman of the southern region of the Civil Engineering Contractors Association warns that most 16 year olds would be better off on benefits than accept the current £93.21 for a 39-hour week (Construction News 1999c). One must not however forget the recessionary climate and the havoc and destruction it brings to construction the construction labour force. Building (1993) reports that pay rates are dictated by the 'brutal economics of the free market' and notes that 'cash in hand' labour is common with rates as low as £2.50 per hour in 1993. Such pay rates are typically evident where foreign labour (Contract Journal 2000e reported that stonemasons from India are allegedly being paid 30p an hour to work on a temple in Wembley, London) has been recruited and thus compounds the problem which this industry has with 'black economy' practices. Current attempts to outlaw such practices through a Government backed Construction Skills Certification Scheme (CSCS) are however being hampered by a low 'take up' from operatives since its 1995 launch. Two industry associations (Confederation of Construction Clients and the Major Contractors Group) have however called for a fully registered workforce and a single registration scheme no later than 2003 (Contract Journal 2000g). It should also not be forgotten that the high wages currently being paid out within construction industry tend to drive up tender prices and increase the likelihood of the UK government adopting inflationary measures to 'cool' an overheating economy. Building (2001b) for example comments that tender figures have risen by up to 30% in London over the past three years, and that this has been fuelled by an insufficient supply of skilled craftspeople.

Given that many operatives continue to stick with the industry through 'bad times', it is possible that a working culture of alienation exists within this sector of the industry. Thus, actions taken by operatives such as pilfering and 'going slow' may be accepted as a 'workers right' and can be considered as legitimate behaviour, and in some instances may even represent a fight for the 'working man'. This could of course be considered comical given that in 'good times' such operatives pay is likely to far exceed many professional salaries. However, the point being made here is that, during recessionary periods, construction operatives may feel that they are exploited and have to work for low pay, (possibly the nationally agreed union negotiated rates) in what may also be an unhealthy and unsafe environment, as a means to 'earn a crust'. Hence during 'boom periods' they may see nothing wrong with exploiting the demand for their services. Such behavioural traits, if in existence, could it is argued be contributory to constructions 'macho culture' and are afterall representative of a free market economy. Indeed, one UK stand up comedian (Harry Enfield) used the occupational role of a plasterer to demonstrate the 'loadasmoney' culture. Furthermore, Building (1999) reports that day rates for finishing trades in London had reached between £120-150 per day and that such trades could hold projects to ransom by demanding what they want.

CONCLUSIONS

The foregoing review has identified a potential root cause of a larger 'skills crisis' which when compared to other strands of construction research is largely undermined. Unlocking information about the perceptions which building craft workers have of their occupational role could support parallel work in a study of the construction professions undertaken by the UK's Tavistock Institute in the 1960's (Tavistock reports 1965 & 1966) and reviewed by Faulkner and Day in the 1980's (Faulkner and Day 1986).

Such research could assist the construction industry's of the world identify the issues which lead to the perceptions of construction work being 'dirty' in its widest meaning. An investigation into whether the 'dirty' mythology prevents the industry attracting school leavers is shared by workers in past. The outcomes of such research could lead to wholesale of just cosmetic changes to work routines which change the perceptions of life as a building tradesman or women at the most optimistic, the work could promote a new mythology which promotes rather than derogates construction work. At a wider, social and political level the research could inform policy makers in Government, both in the department responsible for construction and that for education policy.

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FORECASTING LABOR PRODUCTIVITY FOR THE INTERNAL MORTAR PLASTERING JOB

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ABSTRACT

Internal mortar plastering is a very intensive task which is performed in building construction. labor productivity may be influenced by several factors which are associated either to the content or to the context of the job. For example, the mortar can be applied manually or by projection; the final cover may widely vary in terms of thickness; and so on.

In order to make labor productivity forecast more accurate, the authors studied mortar plastering on construction sites in Brazil, composing a large database (252 workdays) that allowed them to evaluate the influence of several factors on the workers performance. Under the Factor Model principles and using statistical tools (e.g. dispersion Charts, analysis of variance, and linear regression approaches), the data was processed in order to allow labor productivity variation to be understood. For example, factors such as wall geometry, finish cover features, tools used by the workers to move materials on the site, helpers vs. skilled workers rate etc, all affected the labor productivity rate, which varied from 0.35 to 1.18 work hours per square meter.

SOMMAIRE

Parmi les corps d'état du Bâtiment, l'application d'enduit mortier intérieur est une des tâches plus épuisantes, dont la productivité du travail peut être affectée par plusieurs facteurs liés soit au contenu, soit au contexte de travail. Par exemple, l'enduit peut être appliqué manuellement ou par projection, l'épaisseur finale peut varier énormément, etc.

Ayant par but améliorer la précision du calcul estimatif de la productivité ouvrière, les auteurs ont étudié ces tâches pendant 252 journées de travail aux sites brésiliens pour évaluer l'influence des variables qui affectent la productivité et ainsi constituer une considérable base de données. Le traitement des données a été fondé sur les principes du Modèle des Facteurs, ce qui a demandé l'application de quelques outils d'analyse statistique, tels que les courbes de dispersion, la analyse de la variance et la régression linéaire pour établir la compréhension des variations observées sur la productivité.

INTRODUCTION

The Brazilian Construction Industry is nowadays considered to be immersed in a very competitive environment (CARDOSO, 1999). The clients are very quality demanding and the price growth trend implies decreasing construction waste. In order to survive in this type of situation, construction companies have to improve their production processes. Understanding labor productivity variation may be a very important tool to help these companies to be successful in that market (FREITAS et all, 1999).

Mortar coverings are very commonly adopted in the Brazilian buildings. To understand labor demands to produce these products is very important either because of the high costs involved or due to the very labor-demanding features of the service. One should also realize that labor waste is very influenced by the management decisions that can be improved by a correct labor productivity discussion.

This paper firstly deals with some labor productivity definitions. Then it describes the method adopted in order to develop forecasting procedures for the internal mortal plastering job. Next, it presents the calculated rates for the 8 construction sites studied that support the procedure definition task. Finally, the forecasting procedures are shown.

MEASURING LABOR PRODUCTIVITY

Labor productivity definitions

Productivity is the efficiency in transforming inputs into outputs. In the case of internal mortar plastering, labor productivity relates the labor effort (input) to the amount of produced mortar cover (Figure 1).

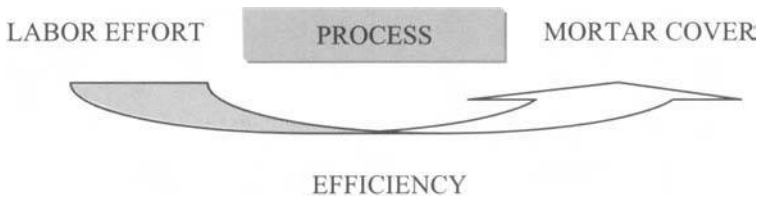


Figure 1 Labor productivity in the internal mortar plastering job.

Labor productivity measurement

This paper adopts, as labor productivity indicator, the unit rate (UR), proposed by THOMAS & YIAKOUMIS (1987), and defined as:

$$UR = Wh / Q \quad (1)$$

where:

Wh = demanded work hours;

Q = quantification of the produced job.

Three aspects have to be addressed in order to allow similar measurements by means of the UR: the inputs measurement; the outputs evaluation; and the adopted period of time.

Labor Measurement

The number of workers to be considered when estimating the labor effort may vary according to the objective of the indicator to be calculated. The authors propose different sizing when grouping the workers. There are three types of workers: the skilled ones, that are directly responsible for the final product execution; the direct helpers, who are the skilled workers nearby and directly help them (for example, providing materials for them to work or clean up the workstation); and the supporting helpers, that also develop helpings tasks (like unloading trucks, organizing stocks, mixing raw materials and sending them to the workstation) but normally far from the skilled workers. Figure 2 defines: the skilled team, composed by the skilled workers; the direct team, that gathers together the skilled workers and the direct helpers; and the global team, that adds the supporting helpers to the direct team.

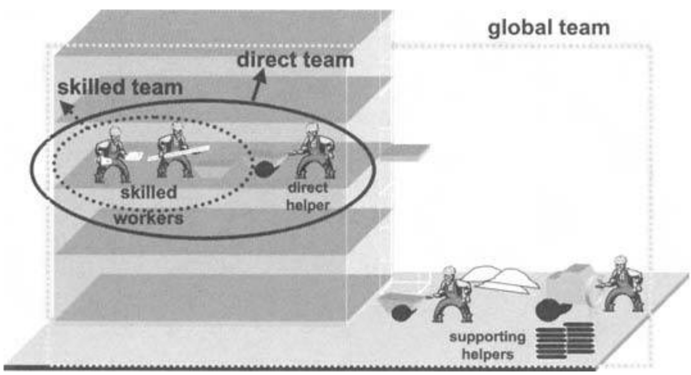


Figure 2 Definition of the teams.

Production measurement

The authors measure the net area of produced mortar cover in order to quantify the output.

Time span

Input and output can be measured on a daily basis or cumulatively (from the first day of the job). Based on these two types of time span consideration, it is possible to estimate the baseline, which would be the UR value that defines a level of efficiency the team is considered able to perform. For more details, see THOMAS at al. (2000) and SOUZA & CARRARO (1999).

UR types

Accordingly to the different approaches one can use to measure inputs, it is possible to calculate: the skilled team unit rate (stUR); the direct team unit rate (dtUR); and the global team unit rate (gtUR). Table 1 shows the different URs calculation for 10 days of job.

Table 1 UR Calculation, for the First 10 Days of an Internal Mortar Plastering Job.

Work day	Q	st Wh	dt Wh	gt Wk	st UR	dt UR	gt UR
	(m2)	Wh	Wh	Wh	(Wh/m2)	(Wh/m2)	(Wh/m2)
1	50	20	29	47	0,40	0,58	0,94
2	130	20	29	47	0,15	0,22	0,36
3	70	20	29	47	0,29	0,41	0,67
4	115	20	29	47	0,17	0,25	0,41
5	125	18	27	45	0,14	0,22	0,36
6	150	20	29	47	0,13	0,19	0,31
7	150	20	29	47	0,13	0,19	0,31
8	100	20	29	47	0,20	0,29	0,47
9	50	20	29	47	0,40	0,58	0,94
10	130	18	27	45	0,14	0,21	0,35

For any type of labor extension consideration, the choice of the time span to be addressed results in three different types of UR: the daily; the cumulative; and the baseline. Chart 1 presents the daily skilled team unit rate (dstUR), the cumulative skilled team unit rate (cstUR), and the baseline for the skilled team (bstUR) related to Table 1 data.

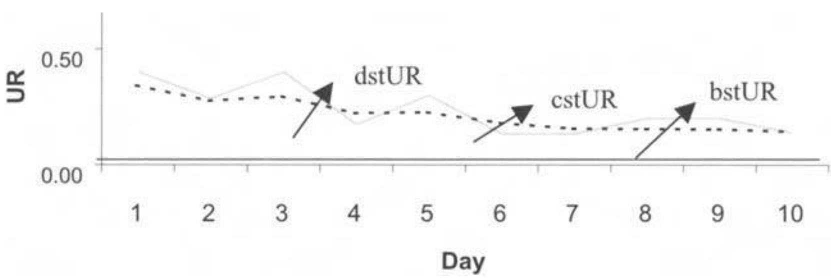


Chart 1 dstUR, cstUR, and bstUR related to the first 10 days of an internal mortar plastering job.

UNDERSTANDING UR VARIATION

The Factor Model as basis for the forecasting procedures to be developed

The Factor Model approach (THOMAS & YIAKOUMIS, 1987) indicates that the UR may vary, in a daily basis in the same job, or from job to job, due to factors related either to the content or to the context of the job. Chart 2 illustrates these ideas. Once the influence of each factor is know, the UR can be expressed as:

$$UR = K0 + K1*F1 + K2*F2 + \ldots + Kn * Fn \quad (2)$$

where:

Ki = influence of the factor Fi;

Fi = factor influencing UR.

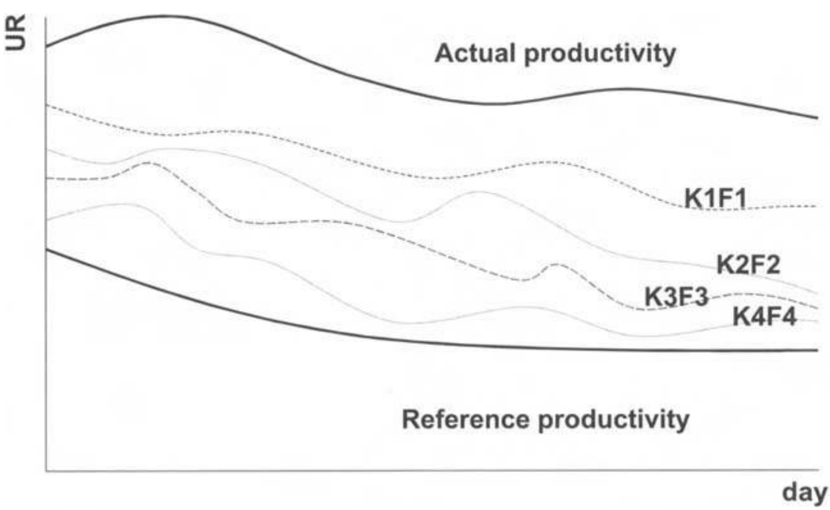


Chart 2 Factor Model approach ideas (adapted from THOMAS & YIAKOUMIS, 1987).

Some factors can be expressed quantitatively (for example, the relation between the number of direct helpers and the number of skilled workers can be 0,67) or qualitatively (for example, the mortar application can be done manually or not). In this last case, Fi is considered to be 1 if the factor is present or 0 if the factor is not present.

Method to develop the forecasting procedures

In order to define rules allowing UR estimation, some statistical tools were used, as illustrated in Figure 3 (for more details see SOUZA, 2001). These tools were applied on the data collected from 8 construction sites where the authors studied the internal mortar plastering job, on a daily basis collection, gathering information about 252 workdays. The idea was to define expressions relating the UR to its relevant influencing factors.

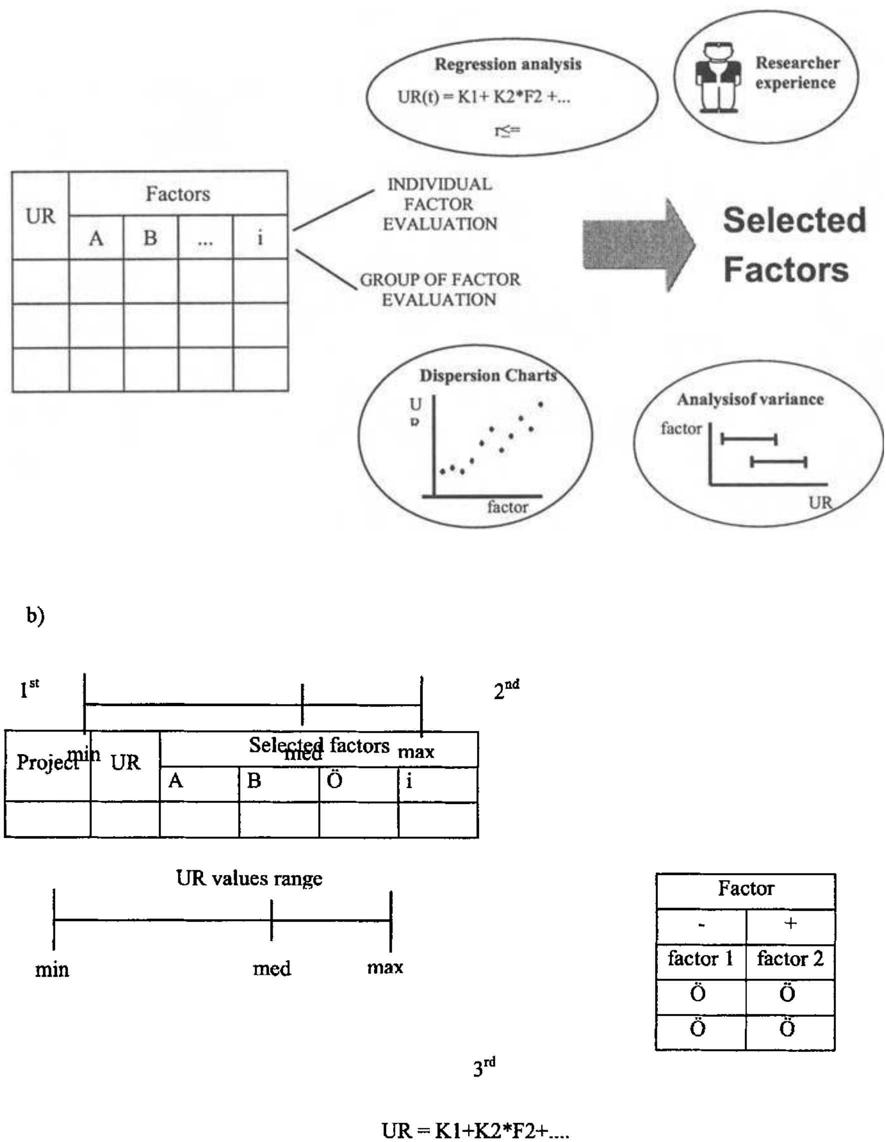


Figure 3 Method for the forecasting procedures development: a) factor selection; b) selected factor influence.

DATA COLLECTION

Table 2 gathers the UR values and the influencing factors that represent the studied jobs. These data allowed the definition of the forecast procedures.

Table 2 URs and influencing factors evaluation for the studied jobs.

Project	Base line	st UR	dt UR	gt UR	AGR	PT	OS	VT	SF	DH/SW	RA	CO	LA
43	0,29	0,41	0,63	0,82	yes	ma	mb	li	ro	0,54	4,76	0,02	1
47[a]	0,51	0,69	1,18	1,53	yes	ma	ms	li	ro	0,67	6,53	0,15	2
69	0,38	0,51	0,94	0,94	no	ma	pu	gr	sm	0,85	11,1	0,02	1
30	0,31	0,40	0,54	0,71	no	ma	pu	gr	sm	0,34	5,66	0,05	1
66	0,53	0,62	0,92	1,11	no	ma	mb	li	sm	0,44	7,55	0,12	1
47b	0,34	0,45	0,47	0,68	yes	me	ms	li	ro	0,00	6,45	0,18	2
80	0,28	0,35	0,35	0,35	yes	me	pu	pu	sm	0,00	8,87	0,11	1

Where:

AGR: available geometric references;

PT: projection technique (ma: manual; me: mechanical);

PS: mortar supply: mortar bags; ms: mortar storage; pu: pump);

VT: vertical transportation (li: lift; pu: pump; gr: gravity force);

SF: surface features (ro: rough; sm: smooth);

DH/SW: direct helpers per skilled workers;

RA: representative area (m^2);

CO: corner (m/m^2);

LA: number of layers.

DEVELOPED FORECASTING PROCEDURES

General ideas

In order to define all the URs that characterize the job, the authors propose the following steps: calculation of bstUR; calculation of cstUR; calculation of cdtUR; and calculation of cgtUR.

The expression that links these URs is shown in Figure 4.

$$\underbrace{\underbrace{\underbrace{[bstUR+(c-bcoUR)]}_{\textbf{cstUR}}x\left(\tfrac{ndt}{nst}+1\right)}_{\textbf{cdtUR}}x\left(\frac{ngt}{ndt}\right)}_{\textbf{cgtUR}}$$

Figure 4 URs forecast.

bstUR forecast

The unit rate can be calculated by the following expression:

$$\text{bstUR} = 0{,}615 + 1{,}02 * \text{CO} - 0{,}0149 * \text{RA} - 0{,}11\ \text{QFS} \quad (3)$$

where:

QFS = qualitative factors score (Table 3 illustrates how to calculate QFS).

Table 3 QFS calculation.

Quantitative factors	QFS			
Surface features	rough: →	1	smooth: →	0
Projection technique	mechanical: →	1	manual: →	0
Layers number	1: →	1	> 1: →	0
Previous execution of geometric references	yes: →	1	partially or no: →	0

cstUR forecast

The cstUR is calculated by adding a "cumulative to baseline" correction unit rate (c-bcoUR) to the bstUR, as showed by the following expression:

$$\text{cstUR} = \text{bstUR} + \text{c-bcoUR} \quad (4)$$

The proposed values for c-bcoUR vary shown in Table 4. The following factors, once present in the job context, induce the adopted c-bcoUR to be higher: short time job (duration of the whole job smaller than 10 days); disruptions by other jobs; lack of materials; equipment troubles.

Table 4 c-bcoUR values variation range.

Minimum	Median	Maximum
0,07	0,12	0,19

cdtUR forecast

The cdtUR is calculated by the expression:

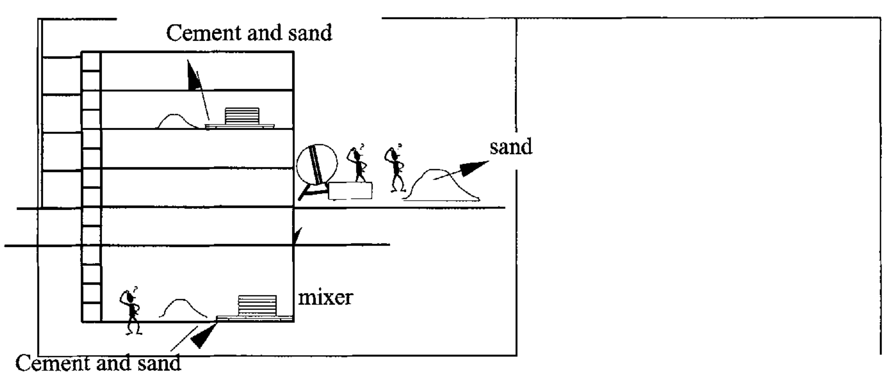
$$\text{cdtUR} = (1 + \text{ndt/nst}) * \text{cstUR} \quad (5)$$

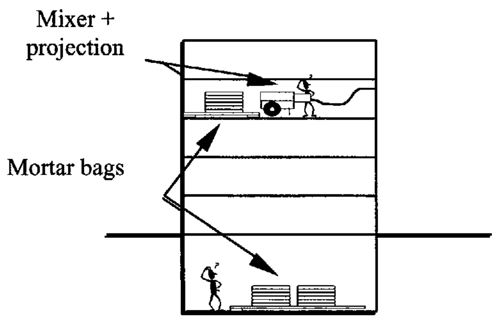
where:

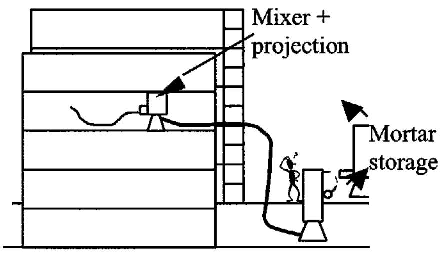
ndt = number of workers in the direct team;

nst = number of skilled workers.

Figure 5 illustrates usual demands for direct helpers and supporting helpers according to the adopted production process. Based on that, one can estimate the relation ndt/nst.




Mixer +
projection
Mortar bags


Mixer +
projection
Mortar
storage

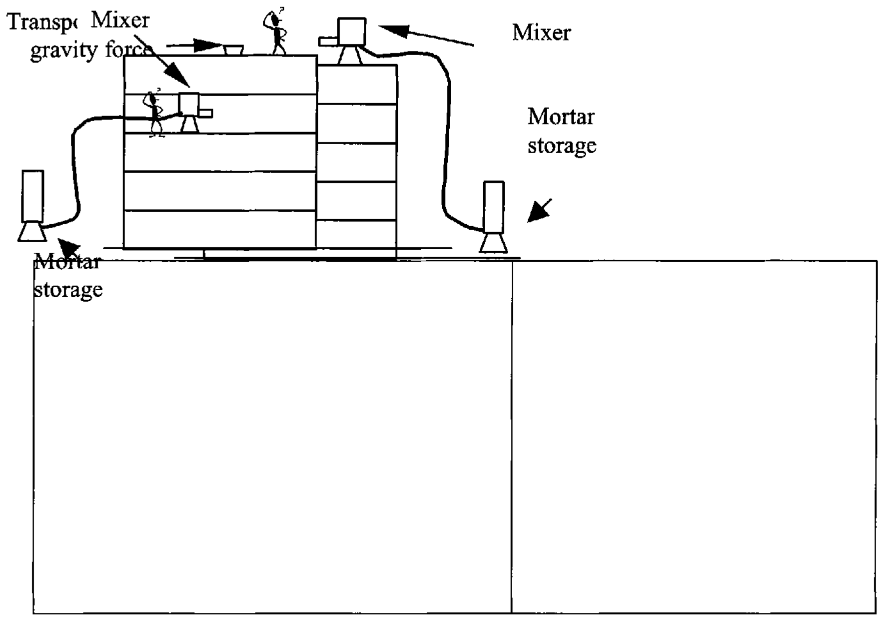


Figure 5 – Usual demands for direct helpers and supporting helpers.

cgtUR forecast

The cgtUR is calculated by the expression:

$$CgtUR = (1 + ngt/ndt) * cgtUR \quad (6)$$

where:

ngt = number of workers in the global team.

Figure 5 also helps ngt/ndt estimation.

FINAL COMMENTS

Labor productivity for internal mortar plastering job can widely vary; it is therefore very important to have a confident way to forecast it, in order to improve the budget process as well the construction management. This paper provides an approach that was based on an extensive data collection, processing, and analysis. More than the forecast procedures, the paper presents definitions that have been discussed internationally, and that will allow further comparisons between the labor productivity and the reasons for higher or lower rates around the world.

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DETERMINISTIC APPROACH APPLICATION TO PRODUCTIVITY ASSESSMENT OF CONCRETE PILES

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ABSTRACT

The installation of pile (drilled shaft) foundations is complicated by an enormous number of problems. They include unseen subsurface obstacles, lack of contractor experience, and site planning. These major problems and other minor ones make it difficult for the estimator to evaluate the piling project productivity and cost. Therefore, this study is designed to assess these problems using the deterministic technique. The piling process activities' duration and productivity are addressed. Data were collected for this study through designed questionnaires, site interviews, and telephone calls to experts in different construction companies. Many variables have been considered in the piling construction process. Six models have been designed to assess productivity and cycle time. Consequently, three sets of charts have been developed, based upon the designed models, to provide the decision-maker with a solid planning, scheduling and control tool for piling projects.

INTRODUCTION

The installation or construction of pile foundations is complicated by an enormous number of problems relating to subsurface obstacles, lack of contractor experience, and site planning difficulties. These problems can be summarized in the following statements. The site pre-investigation usually consists of statistical samples around the foundation area that do not cover the entire area. Soil types differ from site to site due to cohesion or stiffness, natural obstacles, and subsurface infrastructure construction obstacles. Lack of experience in adjusting the pile axis, length, and size present a further complication. Piling machine mechanical and drilling problems must be considered. Problems due to site restrictions and disposal of excavated spoil have great effect on productivity. The rate of steel installation and pouring concrete is impacted by the experience of the steel crew and method of pouring. All these problems, no doubt, greatly affect the production of concrete piles on site. There is a lack of research in this field. Therefore, the objective of this study is to analyze the piling process productivity factors and assess productivity considering most of the above factors.

It is difficult for the estimator to evaluate piling productivity. Therefore, it is necessary to use sophisticated techniques to analyze the problem and determine the closest optimal solution. This study highlights the problem features and solution. The objective of this study is to provide the piling process decision-maker with a tool for assessing piling process productivity, cycle times, and cost of the piling process using the deterministic analysis technique.

CONVENTIONAL (DETERMINISTIC) MODEL DESIGN

The deterministic technique is defined as the technique that uses the statistical mean to represent its variables. In other words, piling process cycle time activities' durations are estimated as crisp numbers (statistical mean for the collected data sample). To build the conventional (deterministic) model for the piling process, construction steps have to be defined in detail. Figure 1 depicts the detailed construction steps of the piling process starting from the axis adjustment until pouring concrete and finishing the pile. The construction steps (algorithm) can be summarized as follows:

1. Adjust the piling machine on the pile axis.
2. Haul with the auger to the drilling place.
3. Start drilling until the auger is filled.
4. Return from the drilling place up to the top of the pile hole.
5. Swing to the unloading area.
6. Unload the dirt in the unloading area.
7. Swing back to the top of the hole.

8. Repeat steps 2 to 7 until the pile is completely drilled.
9. Relocate the machine and start steps 1 to 8.
10. Start erecting the rebar cage using a crane.
11. Erect the concrete pouring tool, either funnel or tremie, into the hole.
12. Use funnel for dry method and tremie for wet method.
13. Start pouring the concrete and finish the pile.

Based on the previously explained algorithm, the deterministic model is designed to assess the productivity of the piling process. The time required to construct a pile has to be determined before productivity assessment. Both piling machine and crane activities' times have to be assessed so that the time required to construct the pile is defined. Consequently, the piling machine is responsible for performing the activities: axis adjustment, drilling, and machine relocation. The crane is responsible for the rest of the activities. Drilling time is the key activity in this process. Hence, to start building the model, consider the following steps:

Drilling Machine Cycle Time Determination:

Drilling has six main activities: hauling to the drilling place, loading the auger (drilling), returning to the top of the hole, swinging to unload area, unload dirt, and swing back to the top of the hole. The pile has to be divided into equal small depth segments (d) to facilitate cycle time calculation as shown in Figure 2. The cycle time at the beginning of the depth segment is, of course, different from that at the end of the depth segment. To consider this concept, the segment depth (d) has to be so small that the cycle time difference between the upper and lower segment's edges is small. Therefore, it is assumed that the cycle time does not change inside each depth segment, which is the center (average) point. Hence, the cycle time at the center of each depth segment represents the cycle time through the entire segment. Then, the cycle time for one segment can be calculated using equation (1) as follows:

Cycle Time (CT) = summation of the six activities times. Then,

$$CT_i = \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \qquad (1)$$

Time to drill one segment (T) is calculated based on equation (1) as follows:

$$T_i = CT_i * (d/h_k) \qquad (2)$$

Hence, the Total Drilling Time (TDT) to drill the pile is calculated based on equation (2) as follows:

$$TDT = \sum T_i$$

$$TDT = CT_1 * (d/h_k) + CT_2 * (d/h_k) + CT_3 * (d/h_k) + \ldots\ldots\ldots\ldots + CT_i * (d/h_k)$$

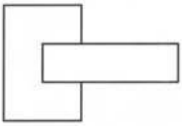
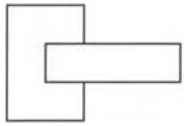
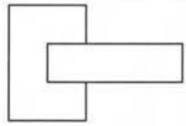
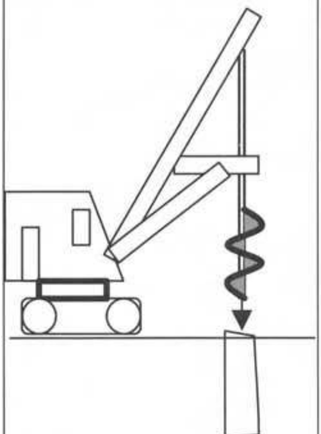
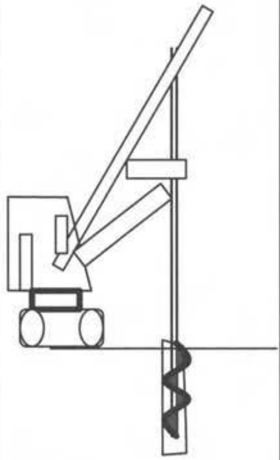
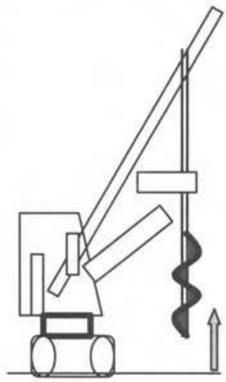
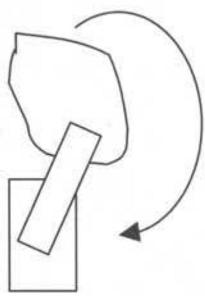
Since the pile is divided into small equal depth segments and the auger height is similar for all segments, then,

$$TDT = (d/h_k)*(CT_1 + CT_2 + CT_3 + \ldots\ldots\ldots\ldots + CT_i)$$

$$TDT = (d/h_k)*(\sum CT_i) \tag{3}$$

From equations (1) and (3), then,

$$TDT = (d/h_k) \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \tag{4}$$

1. Adjusting the Axis and Hauling to Drilling Place	**2. Drilling**	**3. Returning to Top of the Hole**
		
		
4. Swing to Unload Area	**5. Unloading**	**6. Swing Back to Top of the Hole**
		

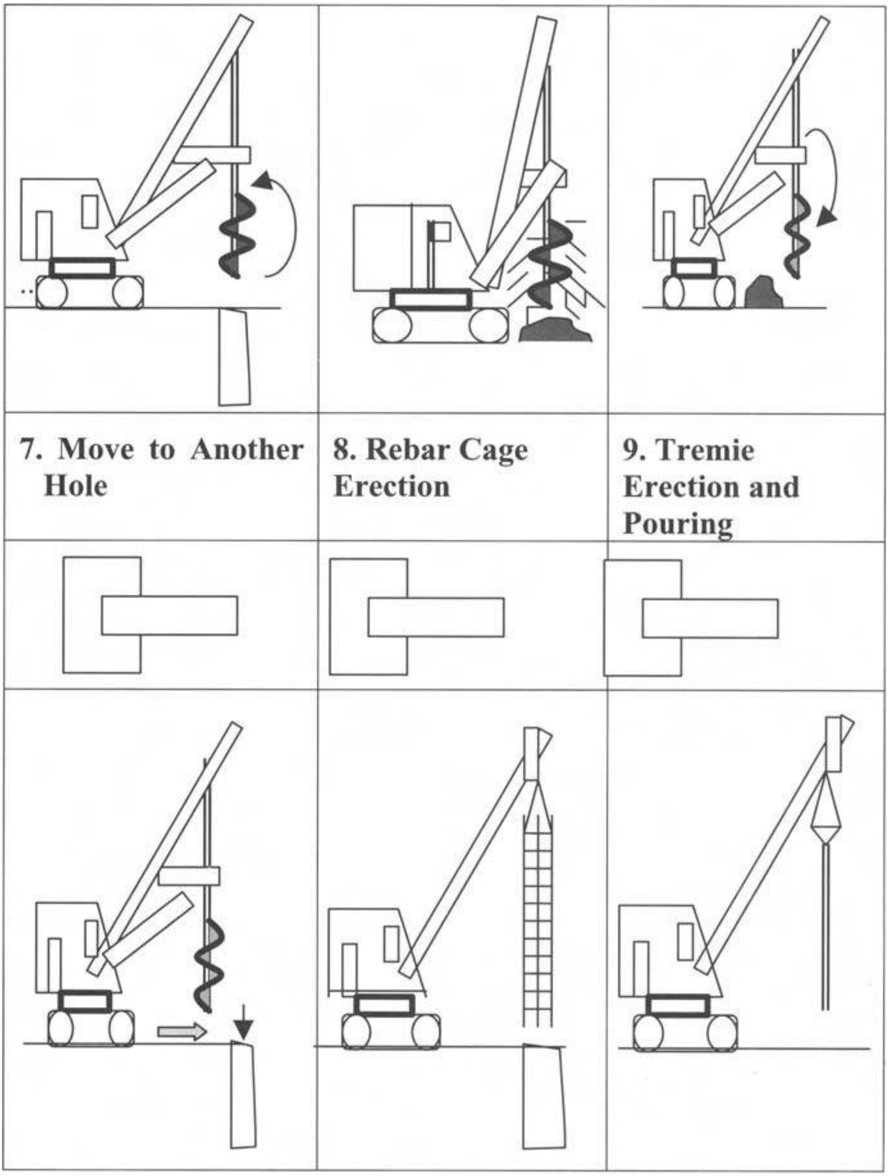


Figure 1 Flow Diagram for Pile Construction Steps.

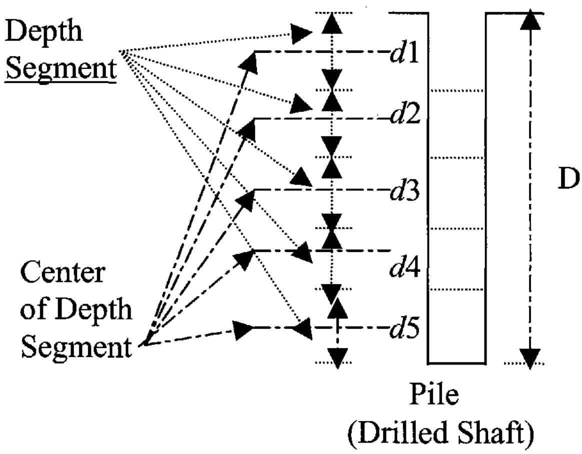


Figure 2 Pile Depth Segments.

Other Activities' Times Determination:

Several other activities have to be considered as well as drilling time, such as cage erection, funnel or tremie erection, concrete pouring, machine relocation, and the pile axis adjustment times. These different activities' times have to be considered in determining the total time to construct a pile. Each activity is discussed in detail as follows:

(a) Rebar Cage Erection (C_r), Funnel Erection (F_r), Tremie Erection (R_r), and Concrete Pouring (P_r) Determination:

C_r, F_r, R_r, and P_r depend upon the pile depth. Four different categories of depth have been considered in this study: 30′, 40′, 50′, and 60′. The term r has been added to the variables to represent the different depth categories.

(b) Wet and Dry Methods Representation:

The only difference between the piling process dry and wet methods of construction is the concrete pouring tool. In the case of the wet method, a tremie has to be used whereas a funnel is used in the dry method. The tremie always takes a longer time to be erected than the funnel. To include both terms in the deterministic model, a switch term has to be used to alternate between the two different values. In other words, a δ term is multiplied by the funnel and tremie expressions to enable the deterministic model to use only one of them according to the suggested method of construction. Therefore, if the method of construction is wet, the term (δ) will enable the tremie expression (R_r) and disable the funnel expression (F_r) and vise versa. The term δ, a 0/1 gate term, can be represented as:

$$\delta = \begin{cases} 1 & \text{if the wet method is used (tremie has to be erected)} \end{cases}$$

if the dry method is used (funnel has to be erected)

Then, in the deterministic productivity model, the term ($1-\delta$) will be multiplied by (F_r) and the term (δ) will be multiplied by (R_r). For example, in case of the dry method $\delta = 0$, then ($1-\delta=1$) opens the gate for the funnel erection time to be included in the deterministic model, the tremie erection time is erased and vise versa.

(c) *Adjusting the Pile Axis (A) and Machine Relocation (M) Times' Determination:*

These two cycle time activities depend upon machine power and the labor crew. Therefore, they will be used as a single value for each.

Based on the discussion in the above points (a), (b), and (c), the Other Activities' Times (*OAT*) can be expressed in equation (5) as follows:

$$OAT = C_r + (1-\delta)*F_r + \delta*R_r + P_r + A + M \tag{5}$$

Total Pile Duration (TD) Determination:

The total duration to install a pile is the sum of the total drilling time (*TDT*) and the other activities' times (*OAT*). Hence, based on equations (4) and (5), the total duration per pile in minutes (*TD*) can be calculated as follows:

$$TD = TDT + OAT$$

$$TD = \left\{ \left[(d/h_k) \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \right] + \left[C_r + (1-\delta)*F_r + \delta*R_r + P_r + A + M \textit{ (minutes)} \right] \right\} \tag{6}$$

Productivity Model Determination:

The productivity model can be determined after calculating the total duration to construct a pile (*TD*). The working hours (*WH*) per day have to be defined to determine how many pile holes can be performed per day. The regular working hours per day are 8. But in this study, the term working hours (*WH*) is left as a variable for the user to adjust according to company policy. Because the *TD* deterministic model (6) uses minutes as a duration unit, the working hours (*WH*) have to be converted to minutes; therefore, the working time per day will be (60**WH*) minutes. Hence, to calculate the productivity, the total working time per day (60**WH*) has to be divided by the total duration (*TD*). The outcome is the number of pile holes that can be constructed per day. But this result considers productive time of 60 minutes per hour; however, this is not realistic. This result only considers the effect of the quantitative factors on productivity and neglects the qualitative factors. Therefore, a term for the effect of qualitative variables has to be considered in the productivity model. This term has been calculated using AHP and fuzzy logic (Zayed, 2001). The final outcome of this qualitative evaluation is the Productivity Index (*PI*). The PI is estimated as 0.7 (Zayed, 2001). The productivity model considers PI as a variable; however, it has the value of 0.7 in the current study. Hence, productivity can be determined using equation (7) as follows:

$$Productivity = 60 * WH * PI / TD \qquad \text{(holes/day)} \qquad (7)$$

Then,

$$Productivity = \frac{60 * WH * PI}{\left\{\left[(d/h_k)\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}\right] + \left[C_r + (1-\delta)*F_r + \delta*R_r + P_r + A + M\right]\right\}} \qquad \text{(holes/day)} \qquad (8)$$

The productivity model in equation (8) gives only the number of holes per day. Productivity can be determined in cy/day or lf/day by multiplying equation (8) by the pile volume and cross-sectional area, respectively. Equation (9) gives the productivity in terms of cy/day whereas equation (10) gives it in terms of linear foot of depth per day. Both equations can be depicted as follows:

$$\text{Productivity} = \frac{1.75 * WH * PI * \phi^2 * i * d \quad \text{(cy/day)}}{\left\{ \left[(d/h_k) \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \right] + \left[C_r + (1\text{-}\delta) * F_r + \delta * R_r + P_r + A + M \right] \right\}} \tag{9}$$

$$\text{Productivity} = \frac{60 * WH * PI * i * d \quad \text{(lf/day)}}{\left\{ \left[(d/h_k) \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \right] + \left[C_r + (1\text{-}\delta) * F_r + \delta * R_r + P_r + A + M \right] \right\}} \tag{10}$$

Because the PI has a value of 0.7, the regular working hours are taken as 8 hrs/day, and the segment's depth (d) is 10′, equations (8), (9), and (10) turn out to be as follows:

$$\text{Productivity} = \frac{336 \quad \text{(holes/day)}}{\left\{ \left[(10/h_k) \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \right] + \left[C_r + (1\text{-}\delta) * F_r + \delta * R_r + P_r + A + M \right] \right\}} \tag{11}$$

$$\text{Productivity} = \frac{98 * \phi^2 * i \quad \text{(cy/day)}}{\left\{ \left[(10/h_k) \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \right] + \left[C_r + (1\text{-}\delta) * F_r + \delta * R_r + P_r + A + M \right] \right\}} \tag{12}$$

$$\text{Productivity} = \frac{3360 * i \quad \text{(lf/day)}}{\left\{ \left[(10/h_k) \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \right] + \left[C_r + (1\text{-}\delta) * F_r + \delta * R_r + P_r + A + M \right] \right\}} \tag{13}$$

DATA COLLECTION

A questionnaire was designed to collect data from contractors and consultants who are specialists in concrete bored pile construction and design. This questionnaire was used to collect the piling process cycle time, productivity, and soil characteristics. Reviewers were asked to provide information based on one of the most average projects that they have done or are currently doing. Accordingly, each questionnaire represents a full set of information about at least one project. Two types of data collection techniques were used in this study. The first technique was *direct data collection*, such as site interviews, site visits to fill data forms, and telephone calls. The second technique utilized a *questionnaire*. For further details, the reader is referred to Zayed (2001).

DETERMINISTIC MODEL APPLICATION

The designed deterministic models have been applied to the piling process collected data to calculate its productivity and cycle time. The productivity has been determined using equations (11), (12), and (13). Equation (11) calculates the productivity in terms of holes per day and equation (12) in terms of cubic yard per day. Equation (13) determines productivity in terms of linear foot of depth per day. The cycle time is calculated using the models in equations (4) and (5).

Drilling Time Model Application to ϕ-18

The deterministic model in equation (4) calculates the total excavation (drilling) time. It is used to develop the chart in Figure 3 that draws the relationship of drilling time against the drilling depth using different auger heights for clay soil with the wet method. Hence, these curves are used to assess the drilling time that is extremely important in planning piling projects. For instance, if a project has a 60' depth with ϕ-18 (18″ diameter pile) in clay soil using a 5' auger height, its drilling time is 21 minutes.

Other Activities Times Model Application to ϕ-18

The drilling time is calculated using equation (4) and the remaining cycle time activities' duration is calculated using equation (5). Figure 4 shows the outcome of the model in equation (5) applied to the ϕ-18 data set. This figure shows other cycle time activities against different pile depths: 30', 40', 50', and 60'. Two curves have been developed to represent the activities times using the wet and the dry construction methods. Figure 4 can be used to assess all cycle time activities except drilling time.

Productivity Model Application to ϕ-18

One of the major goals of this study is to determine the piling process productivity considering different variables, such as auger height, depth, pile size, and soil type. The deterministic productivity model is indicated in equations (11), (12), and (13). The productivity model in equation (11) determines the productivity in holes per day (holes/day) while other equations calculate productivity in cubic yards per day (cy/day) and linear foot per day (lf/day), respectively. Common practice uses the productivity in cy/day or lf/day; therefore, the models in equations (12) and (13) have been developed. Productivity models in the three previous equations have been applied to the available model building and validation data sets. The outcome of model building data set application is shown in Figure 5. It shows the productivity in terms of holes per day for the wet and dry construction methods in clay soil. It provides a set of productivity curves at different depths with a maximum depth of 60', using different auger heights, such as 3', 4', 5', and 6'. The continuous curves represent the productivity using the dry method and the dotted curves represent productivity using the wet method. Hence, for a project in clay soil with a known depth, in the range that is considered in this chart, productivity can be assessed in holes per day. Moreover, the construction method, the drilling tool, and the pouring tool must be defined prior to starting the work.

CONCLUSIONS

The conventional (deterministic) technique is used to assess piling process productivity and cycle time. Several models have been designed to assess these items. Several sets of charts that represent productivity and cycle times have been developed. A comprehensive discussion of the application of these deterministic models to productivity, cycle time, and cost is available in Zayed, 2001.

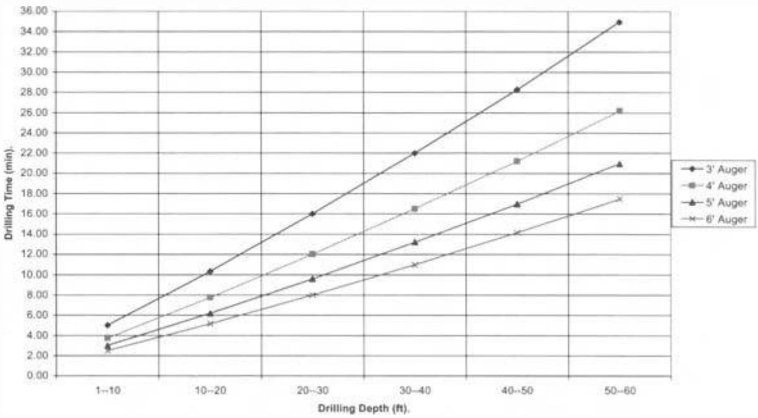


Figure 3 Drilling Time for ϕ-18 Pile in Clay Soil

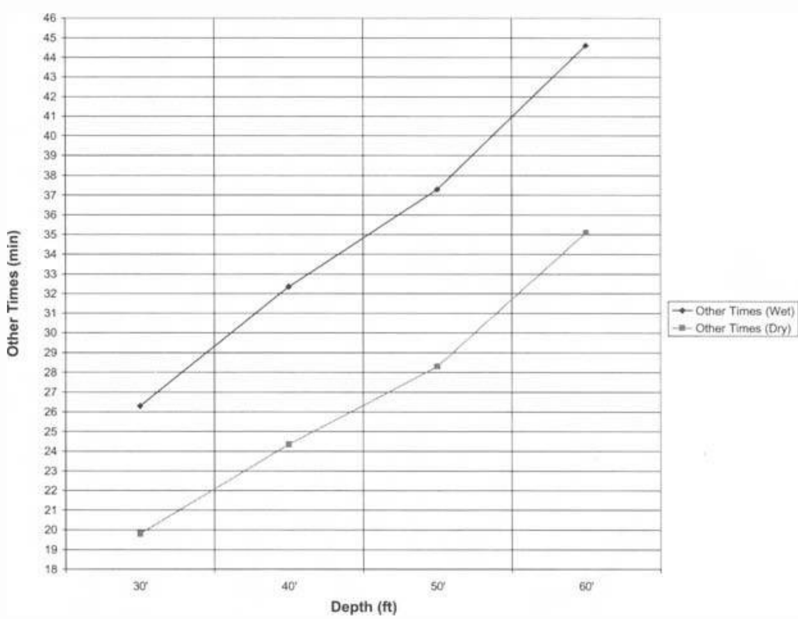


Figure 4 Other Activities Times for ϕ-18 Pile.

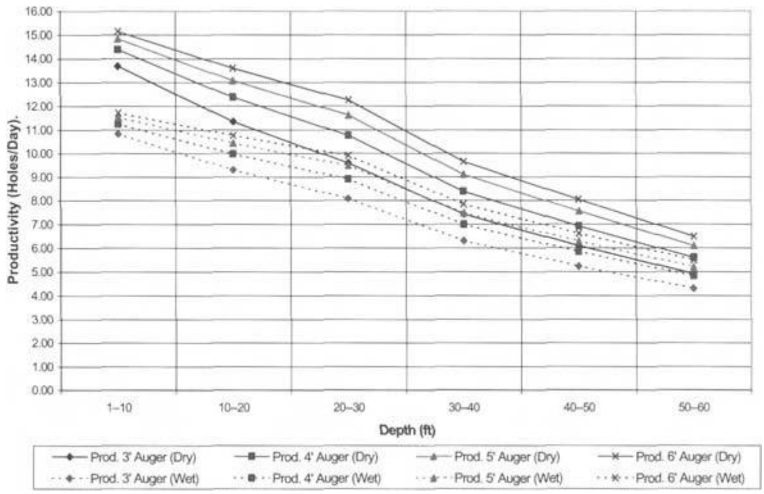


Figure 5 Productivity for ϕ-18 Pile in Clay Soil.

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APPENDIX I: NOTATION

CT_i = Piling machine cycle time at segment *i*.

x_{ij} = Cycle time's activity j estimated time in segment i.

(i = *1, 2, ..., m* and j = *1, 2, ..., n*)

n = Maximum number of cycle time activities, which is 6 in this process.

m = number of chosen depth segments.

T_i = Time to drill segment i.

d = Depth of segment that is equal for all segments (ft).

h_k = Auger height, k = 3, 4, 5, or 6 corresponding to auger heights 3′, 4′, 5′, or 6′, respectively (ft).

TDT = Total Drilling Time per pile.

OAT = Total Other Activites' Time per pile.

C_r = Rebar cage time for depth r. (r = *1, 2, ..., p*)

F_r = Funnel erection time for depth r. (r = *1, 2, ..., p*)

R_r = Tremie erection time for depth r. (r = *1, 2, ..., p*)

P_r = Concrete pouring time for depth r. (r = *1, 2, ..., p*)

A = Adjusting the pile axis time.

M = Machine relocation time.

WH = Working hours per day

PI = Productivity index (qualitative variables effect)

TD = Total duration to construct a pile.

ϕ = Pile diameter (ft)

d = Depth of each segment (ft)

Subscripts and Superscripts

i = Number of segments. It has a range from *1* to *m*.

j = Cycle time activities number. It has a range from *1* to *n*.

k = Different auger heights. $k = 3', 4', 5'$, and $6'$.

r = No. of different depths. $r = 1,2,3,4$ for $30', 40', 50', 60'$ depths, respectively.

p = Max. number of chosen depths. $p = 4$ in this study.

ARE CONSTRUCTION SITES AND MANUFACTURING FACILITIES THE SAME?

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Much energy has been expended over the last ten years in hypothesizing that a construction site should be viewed as a manufacturing facility. On this basis, industrial engineering methods have been applied to the analysis of construction operations. Indeed, manufacturing principles are the basis for concepts of production control and lean construction. These principles are valid in construction only to the extent that construction is like manufacturing. If important differences exist, then their application is like fitting a round peg in a square hole.

OBJECTIVE

The objective of this paper is to highlight the differences between managing a construction project and operating a manufacturing facility. The issues raised in this paper are important to recognize as researchers advocate the principles of lean construction and production management. Differences are highlighted in eight topical areas.

ORIENTATION AND VIEWPOINT

An important philosophical difference between manufacturing operations and construction activities is that manufacturing seeks to manage the process and construction emphasizes producing products. While seemingly a minor point, the process orientation in manufacturing leads to a focus on the methods used while the product orientation in construction leads to a focus on the end product or output. There are significant differences in the way the operation is analyzed and how performance is measured. Also, a manufacturing facility generally has a single cost or profit center, the facility or plant itself, whereas on a construction site, there are numerous cost centers, one for each cost code.

NATURE OF ACTIVITY INTEGRATION

Production processes and scheduling are highly sequential in that a product passes through multiple workstations. At each point, some value is added to the product. Each workstation is staffed with the same numbers of persons each day and the number is based on the nature of the work at that station. The work remains essentially constant. Because the work remains unchanged, much attention can be focused on the method as the way to improve performance.

Construction activities are very different. The work is highly integrated and concurrent. Construction scheduling techniques are much difference from the techniques used to produce a production schedule. For instance, a critical path method (CPM) schedule would have limited or no use in all but a few manufacturing operations. Conversely, the utility of a production (or linear) schedule is limited except for certain construction operations. In concurrent activities, only a fraction of the potential work locations is manned each day. Different crews may occupy a particular work location each day, and the number of craftsmen often varies. The nature of the work changes daily necessitating different skills, information, materials, and support services. The phrase "parade of trades" has sometimes been used to describe construction operations. This phrase applies to sequential operations. Sequential operations occur in construction operations at a macro level, but usually do not occur when a more detailed analysis is made. Thus, construction operations at the activity level are more like modeling a riot than a parade.

PERFORMANCE MEASURES

In manufacturing operations, the facility produces a certain number of products daily. Because the input in terms of materials and labor is essentially constant all the time, the performance of the facility can be equated to the output. Producing 500 gadgets per day is better than producing 450 gadgets per day.

In essence, the total facility or plant operates as a cost center. A workstation does not produce products and does not have a budget against which station performance is measured. One way to improve performance in manufacturing is to make the method more efficient. This gave rise to the work sampling or activity sampling method. The focus in the method is the identification and elimination of unnecessary activities like moving materials or waiting. Another performance enhancement tool is the crew balance chart. The method highlights wasteful steps and reduction of cycle times. Another goal of crew balance charts is the reduction of the number of workers required. This can be effectively done because the steps in the cycle are always the same and the time between cycles is hopefully insignificant.

Construction performance is measured on the basis of input (workhours) per unit of output (quantities). The reason for this measure is because each construction activity is a cost center. The goal is to use the minimum resources to produce s fixed amount o output. Since labor resources can be highly variable, workhours are part of the performance measurement equation.

Unlike manufacturing, construction methods, output, and cycle times change, sometimes on a minute-by-minute basis. This makes the work sampling and crew balance techniques of limited value in all but a few instances. It follows that the best and most lasting way to improve performance is to concentrate on improving the environment in which the work is done, that is, eliminate disruptions.

WORK ENVIRONMENT

The environment in which the work is done refers to sequencing, congestion, availability of resources, weather, and other disruptive events that impair performance. In a manufacturing facility, the work is largely steady-state. The resources are available, the sequence of operations is fixed, and work areas are not congested. The work is done indoors so the weather is not a factor. Thus, manufacturing focuses improvement efforts on the method instead of the environment.

In construction, the environment changes throughout the day. Resources of various types and quantities are needed to support the crew. Improvements in the method are often short-lived because the component or location changes frequently. Because the environment and schedule demands are so dynamic, much attention is focused on the elimination of disruptions. Indeed, over the last ten years, much has been written about the availability of resources (materials, tools, equipment, and information), congestion, sequencing, schedule acceleration, weather and other disruptions. These are all work environment issues and dominate by a wide margin over issues related to work methods.

LEVEL OF UNCERTAINTY

Manufacturing is a rather stable environment. Resources are readily available, work routines are established, and all generally know the production schedule. Disturbances from weather are not a factor. This stability means that the manufacturing facility operates smoothly, and the same work schedule applies each day. With a smooth running schedule, buffers and inventories can be kept to a minimum and pull-driven operations can be practiced.

Construction is very different. Compared to a factory, the environment is very unstable. There are disturbances arising from the weather. Additionally, other schedule disturbances can result from design errors, equipment breakdowns, lack of materials, and other situations. Congestion can also be problematic. Sometimes, congestion is caused by the design resulting in restricted access. A construction site evolves over time. A site one month into a project is not the same as will be observed a year later. These uncertainties mean that different management practices must be applied. For sure, buffers and inventories cannot be reduced to near zero because inventories are an important assurance against uncertainty. In a recent study of steel reinforcement productivity on three projects in Brazil, it was determined that the baseline productivity improved as the buffer size increased. This relationship is illustrated in Fig. 1.

PRODUCT DIVERSITY

Manufacturing facilities have minimal diversity. This condition results in minimal changes to the work schedule or routine. Some larger organizations deal with diversity by building different products at different facilities. For instance, a sedan will not be built at the same facility as a truck. Thus, the resources needed to build diverse products will be nearly the same at a given facility.

Construction is very diverse and must be considered in making crew and assignments. The resource requirements can vary widely. For example, Table 1

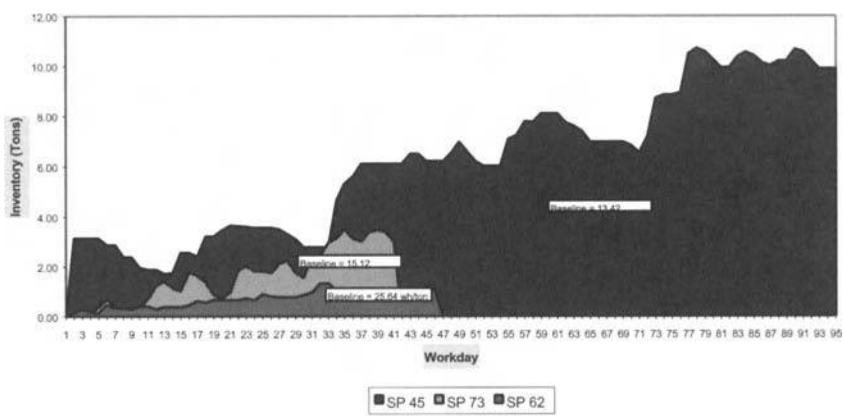

Figure 1. Relationship Between Inventory and Productivity.

shows the formwork components and resource requirements for constructing a bridge. These activities are often ongoing concurrently. Additionally, the stem and cap require significant coordination with the crew assembling the steel reinforcement. The size and resource requirements for concrete placements also vary. The same crew is usually used for each component and the workers are shifted to other bridges as needs arise.

Table 1. Components and Resource Requirements for Bridge Construction.

Component	Productivity (wh/ft^2)	Equipment Resource
Footing	0.090	Manual, built in-place
Abutment	0.098	10 ton crane, built in place
Pier Stem	0.073	60 ton crane, preassembled
Pier Cap	0.065	60 ton crane, preassembled

RESOURCE REQUIREMENTS

Both manufacturing and construction require similar resources, but the characteristics surrounding the use of these resources vary widely. The resources are described by type.

Materials

Construction materials are delivered to the site daily. Many are one-of-a kind items that are made specifically for the project. Delivery schedules must be coordinated and storage and setting in place and alignment must be carefully planned. The efforts of vendors, designers, owners, and contractor must by synchronized. The removal of waste is another important concern.

Manufacturing is largely concerned with the management of vendor relations. Deliveries involve a large number of like (or nearly so) items. While there is much less diversity, delivery schedules can be very tight.

Equipment

Assembly line equipment is usually stationary and is used by a single work team. It is designed to perform one function. Conversely, construction equipment is often designed for multiple purposes and is shared by multiple crews. Even the larger pieces of construction equipment are not stationary and remain on the site for the shortest time frame practical. Construction equipment operates under sometimes harsh conditions and therefore, breakdowns are common.

Information

Information is necessary for all construction and manufacturing operations. However, the form and source differs. In manufacturing, the main source of information is the customer order detailing what is to be produced. Without the order, the product cannot be produced. In construction, the primary information sources are the plans and specifications. However, the work schedule, shop drawings, responses to requests for information, and other correspondence are important and necessary forms of communication. The origin of the communications can be owner, designer, subcontractor, vendor, and other sources.

Labor

Labor is not often considered a manufacturing resource requiring close management. This is because all workstations are manned daily by the same number of workers. Therefore, the number of workers reporting for work each day is generally the same (or nearly so). Thus, work assignments are generally the same.

On a construction site, the workforce gradually increases and peaks at about the 50-70% complete milestone. The work assignments vary daily and the number of workers and the hours worked nearly parallels the amount of work available to perform. If there is more work to perform, scheduled overtime or more craftsmen are an option. Fig. 2 shows the daily workhours on a project involving the installation of 60 miles of underground conduit.

Crew Relationships

Work in manufacturing is largely sequential. The relationship of one work team to another is also sequential in that a team adds value to a product and never returns to work on that particular product again. Many construction operations are also sequential, but sometimes the crew relationships are cooperative or symbiotic. An example serves to illustrate the nature of symbiotic relationships.

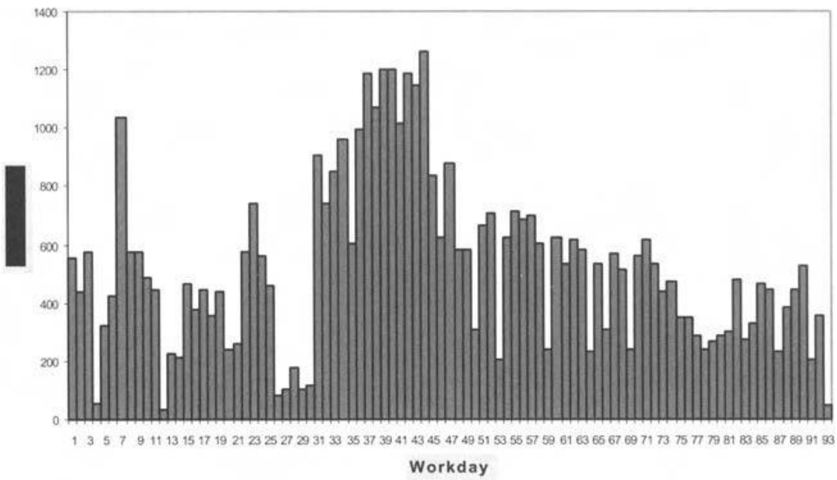

Figure 2. Daily Workhours on Underground Conduit Project.

Suppose a crew of electricians is installing rough in electrical consisting of branch conduit and receptacle boxes. The wall framing must be installed first followed by the rough in electrical work. However, this work must precede the installation of drywall. Thereafter, the finish electrical work can take place. The work of the three crews is said to be symbiotic. In particular, if the framing and drywall are scheduled too near one another, then the rough in electrical crew cannot establish their own pace or work schedule. Their work will be greatly impacted and inefficient.

Symbiotic crew relationships occur infrequently in manufacturing, yet many construction operations are symbiotic. Like the rough in electrical example above, operations that would normally be sequential can become symbiotic is the elapsed time between operations becomes too small. A key determinant is whether the crew can establish its own work pace.

Physical Demands of Construction Work

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ABSTRACT

This paper investigates the feasibility of measuring *in-situ* physical demands for construction laborers performing typical construction work. The measured physical demands are used to characterize work intensity and whether the demands are physically fatiguing. Physiological measures of energy expenditure, including oxygen consumption and heart rate data, were collected as indicators of physical demands. Measurements of physical demands on eighteen (18) construction laborers indicate that most of the workers were working at fatiguing levels according to one or more published guidelines for acceptable levels of energy expenditure, oxygen consumption, and heart rate. The methods described in this paper have wide applications in identifying excessively demanding construction tasks. Work can then be modified to accommodate the abilities of all workers.

INTRODUCTION

With the exception of earthmoving equipment, cranes, and other machinery, construction craft work remains a physically strenuous and demanding occupation. Physically demanding work leads to physical fatigue, which leads to decreased productivity and motivation, inattentiveness, poor judgment, poor quality work, job dissatisfaction, accidents, and injuries. Although studies of energy requirements for construction tasks have been made in the past, most values were collected in the 50s and 60s on young healthy males. The lack of data on other demographic groups has led to speculation regarding the physical demands to which females and older workers may be subjected. The physical demands of today's construction work

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must be determined to provide a sound basis for identifying strenuous tasks and safeguard workers from potential physical fatigue.

Understanding the physical demands of construction work is of great importance in protecting the workforce's safety, health, and productivity. As suggested by Brouha (1967), such understanding is key to the solution of the problem of what a man can do safely. This understanding also allows identifying opportunities for changing the work methods, including investment in more automated tools and equipment; providing appropriate work-rest cycles; or even adjusting expectations of what workers can reasonably be expected to accomplish. These and many other examples of administrative and engineering interventions to reduce physical demands and fatigue would provide endless opportunities to improve construction work today.

Abdelhamid and Everett (1999) demonstrated the feasibility of measuring *in-situ* physical demands of construction activities for a concrete placing and finishing operation using indirect calorimetry techniques. Based on these results, this research investigates the physical demands of construction work performed by construction laborers and evaluates whether these physical demands are excessive. A field study was conducted on 18 randomly selected construction laborers while they were engaged in actual construction work. Physiological measures of energy expenditure, including oxygen consumption and heart rate data, were collected as indicators of physical demands. It is worth noting that the intent of this paper is not to generalize findings to all construction tasks nor to the general construction craft worker population.

Measurements of physical demands on eighteen (18) construction laborers indicate that most of the workers were working at fatiguing levels according to one or more published guidelines for acceptable levels of energy expenditure, oxygen consumption, and heart rate. The methods described in this paper have wide applications in identifying excessively demanding construction tasks. Work can then be modified to accommodate the abilities of all workers.

BACKGROUND

Measurement of physical demands of work, and assessment of physical fatigue and the limitations it may have on worker productivity, has attracted and occupied work physiologists and industrial engineers for many years. Decrease in performance due to fatigue is widely accepted, but no agreement has been reached in trying to quantify this decrease, or in setting acceptable limits for it. Different researchers have approached the measurement of physical demands, and assessment of physical fatigue in a multitude of ways. The most common methods of measuring physical demand are those of measuring the oxygen consumption or oxygen uptake (usually measured in liters of oxygen per minute), during work or exercise, and/or recording the heart rate (measured in beats per minute) associated with the performance of an activity. Oxygen uptake data from direct measurements or estimates from heart rate have also been used to indirectly estimate the energy cost of performing various human activities, which in turn is used to assess potential for physical fatigue.

Measuring Energy Expenditure

Measuring the energy expended by humans at rest or during work is the cornerstone of many disciplines branching from human physiology (e.g., exercise physiology and work physiology). The kilocalorie (kcal) is the unit used for measuring energy. It is defined as the quantity of heat necessary to raise the temperature of 1 kilogram (1 liter) of water 1° Celsius. It is familiar to dieters as the Calorie, and is equal to about 4 BTUs, 1.162 Watt-hours, or 4186 Joules. There are two main ways to measure the energy humans expend: direct and indirect calorimetry.

Direct Calorimetry

Human metabolic processes produce heat. The metabolic rate can be estimated by measuring the rate of heat production. This measuring procedure is termed "direct calorimetry". Direct calorimetry can only be performed in a human calorimeter, which is an airtight, thermally insulated chamber. A person can literally live in this chamber, while the heat produced from metabolic processes can be accurately measured during rest or work periods.

Measuring energy expenditure using direct calorimetry can be extremely accurate. However, human calorimeters are very expensive to build and operate and are not portable. These limitations restrict the use of direct calorimetry to academic research performed in laboratory settings.

In-direct Calorimetry

The idea behind indirect calorimetry is quite simple. Since oxygen is used and carbon dioxide is produced during energy-yielding reactions, exhaled air contains less oxygen and more carbon dioxide than inhaled air. The difference in composition between inspired and expired air volumes reflects the body's release of energy through aerobic metabolic reactions. Research has shown that for every liter of oxygen consumed, 4.83 kilocalories of energy, on average, are produced. Thus, by measuring the rate of oxygen consumption before, during, and after performance of physical activities, the total energy expended by a human can be estimated. It should be noted that the conversion multiplier varies slightly depending on a physiological attribute termed the "Respiratory Quotient". This method of estimating energy expenditure from oxygen uptake is referred to as "indirect calorimetry". Compared to direct calorimetry, indirect calorimetry provides a reasonably accurate, portable, and relatively inexpensive method of measuring energy expenditure.

Oxygen Uptake Measurements

Measuring oxygen uptake through indirect calorimetry involves two main techniques: closed-circuit and open-circuit spirometry. In a closed-circuit spirometer, the subject re-inhales air that is in the spirometer, hence the name closed-circuit. Closed-circuit spirometry is used mainly to estimate energy expenditure during resting or light-intensity exercise. In addition, closed-circuit spirometers are bulky, hence restricting their portability.

In an open-circuit spirometer, the subject inhales ambient air with known concentrations of oxygen, carbon dioxide, and nitrogen. Many open-circuit spirometry devices exist such as portable spirometers, bag techniques (the most famous is the Douglas bag), and computerized instrumentation. Due to portability, open-circuit spirometry is the most practical and widely used method for measuring oxygen uptake.

METHODS

Measuring Equipment

In this study, oxygen uptake measurements were made using indirect calorimetry techniques. The AeroSport KB1-C ambulatory metabolic analysis open-circuit spirometery-based system (AeroSport, Inc., Ann Arbor, Michigan) was the system chosen for measuring oxygen uptake (VO_2) and other physiologic attributes. Energy expenditure was later derived from the measured VO_2.

The KB1-C metabolic system contains electronic instrumentation, battery, oxygen and carbon dioxide sensors, and telemetry connections to a microprocessor that permits radio transmissions of up to 300 meters (1000 feet) to a receiver and computer. The KB1-C is compact (7.5 x 15 x 5 cm) and lightweight (1.13 kg) making it easy to transport during physical activity. The data module and batteries may be worn with a three point vest or a contoured waist belt. With this system, subjects are also required to wear a mouth piece and a nose clip or a face mask. In either case, subjects still breathe ambient air. The KB1-C can be programmed to measure oxygen uptake at 20, 40, or 60-second intervals.

A separate heart rate monitor system (Polar Vantage XL) was used for measuring heart rate. With this system, the HR is measured using a chest band fitted with a sensor/transmitter that measures the HR and transmits it to a microprocessor in the AeroSport KB1-C unit.

Measurement Procedures

Oxygen uptake and heart rate measurements for 18 construction laborers from 3 different sites were collected while construction work was being performed under normal work conditions. For each subject, VO_2 and HR data were collected at 20-second intervals for a period ranging from 30-60 minutes. Data was collected long enough to ensure that steady state VO_2 and HR had been reached and that several typical work or work-rest cycles had been completed.

In most cases, workers indicated that the work they were performing was representative of the whole day. When workers indicated that they perform other activities over the course of a day, data was collected for those activities when they occurred. Observed work activities were videotaped to facilitate description and documentation of tasks.

Evaluation Methods

The physiological demands of a task as a measure of physical demand is only one side of the story, the so-called assessment phase in the literature, and the other important side being the evaluation phase. The objective of the evaluation phase is to determine whether the physical demand of a certain task is excessive, and whether the worker performing the task may suffer from physical fatigue. Workload evaluation techniques include classification of work severity based on published guidelines for oxygen uptake and heart rate, and evaluation of physical fatigue potential based on absolute energy expenditure and heart rate values

Use of absolute energy expenditure as a workload criteria

The average young adult male, 5 feet 8 inches (173 cm) tall, weighing 160 pounds (72.6 kg), in good physical condition, can develop power (energy/time) at the rate of about 5 kilocalories (kcal) per minute for several hours (Astrand and Rodahl 1986). A widely used rule of thumb is that activities requiring less than 5 $kcal \cdot min^{-1}$ can be performed continually for a work shift without overly taxing the worker. An activity requiring more than 5 $kcal \cdot min^{-1}$ can be performed for a limited time before the worker needs a rest to recoup energy from stores within the body (Oglesby at al. 1989).

The rest duration required for a worker varies greatly with the intensity and duration of the work cycle itself, as well as with individual differences. According to Brouha (1967) a worker should be allowed to rest until all physiological functions such as heart rate, blood pressure, oxygen uptake, rate of perspiration, body temperature, chemical composition of the blood and urine, return to *pre-work* levels. As stated by Brouha (1967): " *When mechanical work stops, physiological work continues above the resting rate until recovery is complete*".

Heart rate as a workload criteria

Brouha (1967) has suggested that an average HR of 110 beat $\cdot$ min^{-1} over an 8-hour shift should not be exceeded for industrial workers. Other researches have introduced different criteria by distinguishing between HR at rest and HR under physical work. The individual's general fitness level, duration of work, and level of work stress may all affect HR.

Muller (1950) suggested that when the HR remains constant at a prolonged uniform level of work, this HR may be considered as the permanent work HR. Research has shown that if an individual's HR at rest is known, the value of HR for permanent work lies approximately 40 beats above that (Kuhlmann 1985). Muller (1962) also emphasized the importance of recording the time required for recovery or "normalization" of the HR after a work activity has been finished. According to Muller, "the sum of heart beats during the recovery time (sum of recovery heart rate) is proportional to the degree to which the permanent performance limit has been exceeded."

RESULTS AND DISCUSSION

The data collected for the construction laborers is shown in Table 1.

Table 1 Collected physiologic data for construction laborers

Subject [1]	Activity [2]	Mean VO_2 (liter · min^{-1}) [3]	Standard Deviation VO_2 (liter · min^{-1}) [4]	Mean HR (beats. min^{-1}) [5]	HR Standard Deviation (beats.min^{-1}) [6]	Estimated Energy Expenditure (kcal · min^{-1}) [7]
1	1	0.89	0.12	113	6	4.30
2	2	1.48	0.35	131	11	7.15
3	3	0.46	0.23	106	6	2.22
4	4	1.24	0.34	109	16	5.99
5	5	0.8	0.42	131	11	3.86
5	6	0.71	0.29	124	16	3.43
6	7	0.58	0.13	107	10	2.80
7	8	0.8	0.16	131	5	3.86
7	9	0.67	0.14	116	6	3.24
7	10	1.1	0.18	117	5	5.31
8	11	0.78	0.17	137	12	3.77
8	12	0.94	0.27	129	11	4.54
9	13	0.71	0.27	87	9	3.43
10	14	0.66	0.21	98	9	3.19
11	15	1.33	0.31	142	14	6.42
12	16	0.75	0.27	94	11	3.62
13	17	1	0.28	123	12	4.83
14	18	0.5	0.28	107	9	2.42
15	19	1.43	0.32	126	13	6.91
16	20	0.75	0.25	101	9	3.62
17	21	0.78	0.12	94	16	3.77
18	22	0.75	0.09	115	4	3.62

Classification of the physical demand for physical fatigue potential are shown in Table 2 and indicate the following:

1. Based on energy expenditure values, 23% of the construction workers in the study were working at a fatiguing rate

2. Based on mean heart rate values, 60% of the of the construction workers in the study were working at a fatiguing rate.

The results clearly indicate that workers in this study are facing more problems with cardiovascular responses than with energy demands. These problems reflect a myriad of factors such as heat stress exposure, heavy static exertions, and/or general health problems.

In any case, it is clear that these construction workers routinely exceed generally accepted thresholds for sustained energy expenditure, VO_2 and HR. It should come as no surprise that these workers are exhausted at the end of the day and may not be fully recovered at the beginning of the next work shift. Few workers can sustain this level of performance. Many burn out and seek alternative, less demanding, work. If alternative work cannot be found, the worker faces the dilemma of continuing at a job that causes excess fatigue, or perhaps dropping out of the workforce.

Table 2 Evaluation of worker physiological data based on contemporary guidelines

Subject [1]	Activity [2]	Classification by Energy Expenditure [3]	Classification by Mean HR [4]
1	1	Not Fatiguing	Fatiguing
2	2	Fatiguing	Fatiguing
3	3	Not Fatiguing	Not Fatiguing
4	4	Fatiguing	Not Fatiguing
5	5	Not Fatiguing	Fatiguing
5	6	Not Fatiguing	Fatiguing
6	7	Not Fatiguing	Not Fatiguing
7	8	Not Fatiguing	Fatiguing
7	9	Not Fatiguing	Fatiguing
7	10	Fatiguing	Fatiguing
8	11	Not Fatiguing	Fatiguing
8	12	Not Fatiguing	Fatiguing
9	13	Not Fatiguing	Not Fatiguing
10	14	Not Fatiguing	Not Fatiguing
11	15	Fatiguing	Fatiguing
12	16	Not Fatiguing	Not Fatiguing
13	17	Not Fatiguing	Fatiguing
14	18	Not Fatiguing	Not Fatiguing
15	19	Fatiguing	Fatiguing
16	20	Not Fatiguing	Not Fatiguing
17	21	Not Fatiguing	Not Fatiguing
18	22	Not Fatiguing	Fatiguing

CONCLUSION

This paper investigated the physical demands for individual construction laborers performing their normal work in the field. Physical fatigue potential was evaluated based on work intensity standards. The results reveal that these laborers routinely exceed generally accepted thresholds for physiological indicators of workload and are at risk for developing physical fatigue. This may lead to decreased productivity and motivation, inattentiveness, poor judgment, poor quality work, job dissatisfaction, accidents, and injuries.

For an industry taking its first steps in occupational physiology, the physiological demands of construction work need to be measured and evaluated using observational data collected from real-life situations. Through the replication of this study on other types of work, management and labor would have better chances to identify opportunities to reduce physical demands and physical fatigue, and cooperate in introducing changes in work procedures and methods to accommodate the abilities of all workers while improving productivity.

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Reducing Surveyor Variability Utilizing Social Judgement Theory – A Pilot Study

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ABSTRACT

Surveyor Variability has been identified as a major cause of unreliable data collection from condition surveys. This paper investigates the use of Social Judgement Theory (SJT) as a potential mechanism whereby the individual judgement polices of surveyors may be elicited. The results from the research described in this paper indicate that SJT may be a valuable tool in achieving more consistent survey results.

INTRODUCTION

We define surveyor variability as the situation whereby two or more surveyors, surveying the same building and having the same evidence of building condition available to them, arrive at different survey reports. Previous research has identified the potential impact of surveyor variability (Kempton et al, 2000; Kempton et al, 2001). The research presented in this paper reports on the method of Social Judgement Theory – a model of a surveyor's judgements where the varying values of surveyors, in terms of the importance they give to building elements, can be elicited by using the regression formula.

The results of the research can be utilised to reduce the amount of variability in surveys by targeting training at individual surveyors and/ or recalibrating survey results.

THE SOCIAL JUDGEMENT THEORY METHOD

The Social Judgement Theory (SJT) method was developed by Egon Brunswick in the 1950's (Brunswick, 1952; Brunswick, 1956). It further evolved to the present day and has become a widely used tool by psychologists.

A Judge (or decision-maker) bases his judgement (or decision) on, among other things, the way in which they weight (or give importance to) the various criteria that form the basis of a given problem. Brunswick modelled the relationship between an 'ecology' (the worldview that a decision is based on), cues emitting from that ecology (aspects of the ecology that the Judge takes into account when making a decision) and cue weights (the importance the Judge gives to each cue).

The model is known as the lens model because of the similarity of the diagrammatic representation of the model to a convex lens. The classic lens model proposed by Brunswick is shown in Figure 1.

Explanation of Terms

1: The Ecology (Environment): The ecology is the judgement task environment a Judge faces. Such an ecology could be judgements on weather forecasts (Lusk and Hammond 1991), judgements as to the vulnerability of a dwelling to burglary (Shaw and Gifford, 1994) and the desirability of land for investment (Burnside, 1994). **2:Subject (Judge)**: This side of the model represents the Judge's 'view' of the ecology as represented by the judgements rendered. **3: Cues (X_1, X_2..X_n)**: Cues are the factors that a Judge takes into account when forming a decision. Examples could be student exam marks (cues) in the case of deciding to admit students to University (ecology), whether a dwelling has good security features (cues) in assessing risk of burglary (ecology) and the presence of edible shrubs (cues) in land value (ecology) judgements. **4: Correct Weights**: These are the weights (the importance) of the different cues in the final judgement. For ecological weights, the actual outcome is known, therefore the weights are an accurate reflection of the ecological criterion. **5: Judged Weights**: These are the weights (the level of importance given) applied to each cue by the Judge. These weights may not necessarily match the correct weights. **6: True State (Y_a)**: This is the actual outcome of a series of cues, e.g. in a weather forecasting judgement, if cloud cover is more than 60%, temperature is 9 degrees, and wind speed is low, then the actual outcome is a burst of rain in one hour. **7: Judged State (Y_j)**: This is the outcome given by a Judge based on the cues and cue weights as applied to the ecology by the Judge. For instance the Judge might decide that, for the above example, the likelihood of a burst of rain would be two hours. **8: R_a**: The level of Agreement: R_a is a measure of how well a judged state matches the true ecological state. In the forecasting example, the difference (i.e. R_a) would be 1 hour.

The classic model represents an ecology for which there is an actual objective outcome. In that situation R_a may be employed to rate a judgement in direct relation to the actual outcome (e.g. in the weather forecasting judgement above the Judge would be in 'error' by one hour).

In many cases, however, an objective measurement is not available. This can be the case with a house condition survey. Because two surveyors disagree with the extent and scope of a repair to a dwelling, it does not necessarily mean that one or other is right or wrong (Kempton et al, 2000). It may be simply a difference in opinion, where both opinions are valid. SJT overcomes this situation because the relative weights for given cues can still be gained. Therefore, for a sample of judges, one Judge's judgement policy can be compared with another in the sample. The sample judges can also be compared with some 'pseudo' benchmark, for example, the condition rating of a dwelling expected by the survey manager. Figure 2, showing the lens model design for the pilot study, shows the procedure for employing the SJT method where no actual value of the ecology is known.

In essence, the lens model design seeks to elicit the importance that a Judge gives to individual cues in a judgement task. The cues are grouped together and presented in a cue profile – that is the configuration of cues used to present a particular case for judgement. The Judge gives an overall judgement on each cue profile - known as the judgement measure. The results from such a study attempt to show the differing judgement policies of individuals.

Cue Identification and Number of Cues in Profiles

The number of cues in a profile should be kept to as small a number as possible. It has been recommended (Cooksey, 1996) that nine or fewer cues should be used. Cue numbers beyond this have been found to stretch the cognitive capacity of judges. A study by Miller (Miller, 1956) found that the number of independent chunks of information that could be dealt with in human short-term memory was 7 Plus/ Minus 2 chunks.

Cue identification can be undertaken by a variety of methods. Soliciting expert opinion (either via a structured/semi-structured interview or by other survey methods such as a questionnaire) as to the most representative cues is one method. The researcher's knowledge of a particular area has also proved a valid method to identify pertinent cues for the study (Cooksey, 1996).

Obtaining Values for the Cues

A number of methods for allocating values to cues within particular profiles are possible. The value of a cue should aim (as with the cue profile itself) to represent the real life ecology as closely as possible. The strongest case for representing the ecological cue values would be to sample actual cases of profiles. It is sometimes not possible to use real cases. In this case the researcher must use alternative methods. If there is really no way of utilising actual data, there is nothing intrinsically wrong with the researcher using 'educated guesses' as to the cue values, if the researcher possesses a good knowledge of the judgement domain. However this is not as defensible an argument for ecology representation as using real cases.

Presentation of Cue Profiles

Many different methods of cue presentation have been employed in SJT studies. Actual examples of cue presentation can be found in Steinmann et al (1977) who employed a graphical method when studying land acquisition judgements. This involved the various cues being presented by means of bar charts to show the 'quantity' of a particular cue. Anderson (1977) used verbal presentation when studying teacher quality – a verbal description of individual student traits was given. Shaw and Gifford (1994) used photographic profiles when studying the vulnerability of dwellings to burglary. Burnside (1994) used both photographic and verbal methods for presenting cues for the judgement of changes in land condition.

The Judgement Measure

To fit the regression model (see later section 2.7) an overall judgement (the judgement measure) must be obtained from each cue profile. The judgement measure can take many different forms. Judgements do, however, usually conform to some sort of numeric scale.

Actual examples of methods of eliciting the judgement measure can be found in Lusk and Hammond (1991) who give an example of a concrete judgement measure relating to a judgement of weather forecasting. Judges were asked to give an actual time in forecasting time to a microburst of rain. Holzworth and Pipping (1985) give an example of numerical scales anchored at both ends (i.e. a scale with a definite upper and lower parameter set e.g. 1 – 10) in a study of situations where a police officer might draw his weapon. Graphical scales were used by Kirwan et al (1983) in a study of prognosis of arthritis. Each Judge gave a judgement on a particular profile by placing a mark on scaled line between two parameters. Zimmer (1980) employed categorical measures in a study of judgements of potential company failure. Categories could consist of e.g. a YES/ NO type response.

Number of Cue Profiles to Include in a Study

Cooksey (1996) recommends a number of cues to number of profiles ratio of between 10:1 and 5:1. For instance in a study comprising six cues the preferable number of profiles presented to a Judge should be 60 and the minimum should be 30.

Capturing Judgement Policies: Multiple Regression (MR)

The technique used to model each Judge's policy is MR. By using MR, a weight (coefficient) can be calculated for each predictor (i.e. cue) in the judgement task. The equation uses the value of each predictor to measure its impact on the final outcome. The regression equation is defined as:

$$Y_a = \{ \underbrace{B_0 + (B_1X_1) + (B_2X_2) + \ldots.(B_nX_n)}_{Y_j} \} + \varepsilon \tag{1}$$

Where: $\mathbf{Y_j}$ = The predicated Outcome; $\mathbf{B_0}$ = The Regression Constant (the predicated value of Y_j when all other variables are held at zero); $\mathbf{X_1..X_n}$ = The Predictor Variables; $\mathbf{B_1..B_n}$ = Regression Coefficients for each Variable where each Coefficient represents the amount Y_j would change if it's associated Variable value was changed by one unit and all other Variables were held constant; $\boldsymbol{\varepsilon}$ = The Error of the predicted outcome of Y_j when compared to an actual outcome (in our terms '$\mathbf{R_a}$' – where available). The addition of $\boldsymbol{\varepsilon}$ to the predicated outcome gives us the actual outcome i.e. $\mathbf{Y_a}$

Based on a given value for each predictor, a particular Judge's final outcome can be predicted by applying the weights (i.e. $B_1..B_n$) given by the results of the judgement task to the value of the predictor variable.

Mathematical arguments for the use of different weighting schemes abound (Stewart, 1988). However for profiles that have cue values all on the same scale, unscaled regression coefficients (Beta Weights) are suitable. If cue values are represented in different units e.g. units of money and percentages, it would not be feasible to use unscaled coefficients, standardised coefficients would be required (i.e. basing the weights in relation to the Judges standard deviations for the different cues).

PILOT STUDY RESEARCH DESIGN

The Ecology

The Ecology for this study was the exterior of a domestic dwelling. If a particular surveyor has a propensity to mark certain elements more strictly (i.e. give more weight to a certain part of the decision problem) than others, the consistency of the survey may be compromised. For a given sample of surveyors, the different ways in which they weight different building elements would lead to inconsistent results over a range of dwellings. The study is shown diagrammatically in relation to the lens model below. It can be noted that there is no real ecological outcome and therefore no potential for R_a. The "Ecology" side of the model being represented by a dotted line denotes this.

Cue Presentation

Several different possible methods of presenting the cues to the judges were considered, including videos of dwellings and photographic case studies. However, given that the point of the exercise is to try to understand the importance Judges give to particular cues, the use of video and photographic material was discounted. If such media had been used, it might not be certain which cues the Judge actually used. For instance the age of the dwelling, perceived tenure, style of decoration, the surrounding area, etc may have influenced judgements. It was therefore decided to present the cues in a verbal format.

To add a sense of reality to the exercise, a covering page was added to the booklet explaining that the actual condition of each element in each profile had been gained by a telephone interview with the dwelling occupier. The covering note further explained that the point of the exercise was to try to see if 'surveyors' (i.e. the participants) could judge the approximate overall condition of the dwelling from the information provided by the occupier. The covering page is shown in Figure 3.

A booklet of cue profiles (n=30) was presented to each judge. A typical profile is shown in Figure 4. A profile consisted of four elements i.e. Roof, Walls, Windows and External Doors. Each element had a series of questions, and underneath the question was the response given by the occupier. Each profile in the series had different mixes of occupier response in terms of description of the condition of an element,

Judges made a rating of each element's condition and gave an overall judgement for each profile (i.e. the judgement measure). Element and overall condition were given in a simple Likert scale of 1-9 where 1 represented the best condition and 9 represented the worst condition. The judgement measure would be defined as a numerical scale anchored at both ends.

Selection of Judges

The judges (n = 10) used were all involved in technical aspects of the built environment They all had good knowledge of domestic construction techniques, and were all qualified to at least first degree level in their particular specialisms. All Judges were male and their ages ranged from mid-twenties to mid -forties. No particular reward was offered to any of the judges for taking part in the study. All agreed to give their time freely.

Capturing Judgement Policies

Judgements were captured in terms of the weights given by each Judge to the individual cues presented. As stated an actual overall condition rating was not available. The Author filled in a cue profile booklet and used those results as the baseline to compare the judges weighting policies. The regression equation (see equation 1) was utilised to achieve beta weights for each Judge.

RESULTS

The coefficients for each Judge for each element, based on the weights for each cue given by the authors, and the final outcome given by the Judge is shown in Table 1 and displayed graphically in Figure 5. Each surveyor (Judge) is identified by a number, the column headed 'BL' are the author's derived coefficients i.e. the author's individual element ratings and final judgements were used in the regression formula.

Table 1: Coefficients for each Judge

	Judge #										
Element	1	2	3	4	5	6	7	8	9	10	BL
Constant	2.69	2.90	1.56	2.70	4.36	0.34	1.44	1.46	0.16	2.56	2.38
Roof	0.25	0.27	0.26	-0.04	0.14	0.15	0.28	0.31	0.17	0.31	0.42
Walls	0.09	0.05	0.09	0.18	0.12	0.29	0.48	0.28	0.32	0.24	0.20
Windows	0.11	0.05	0.08	0.10	0.12	0.35	-0.20	-0.03	0.23	-0.24	0.13
Doors	0.04	0.24	0.05	0.17	0.09	0.11	0.15	0.15	0.16	0.44	0.05

DISCUSSION

The results from the study show that different judges do seem to have different judgement policies. By comparing the different weights for each element for each Judge, the importance each Judge gives to each element can be seen. A statistical summary of the weights is shown in Table 2 below (note the Baseline results are not included in Table 2).

Table 2: Statistical analysis of Judges cue weights

Element	Mean	Max	Min	StdDev
Constant	2.02	4.357	0.16	1.27
Roof	0.21	0.313	-0.04	0.11
Walls	0.21	0.485	0.05	0.13
Windows	0.06	0.346	-0.24	0.18
Doors	0.16	0.436	0.04	0.11

Even at the most basic level, Table 3 showing a simple analysis of each Judges final judgements for each profile (on a scale 1-9), indicates the propensity of individuals to rate profiles more or less strictly in relation to other Judges.

Table 3: The Propensity of Individual Judges to Mark 'Strictly' or 'Weakly'

Judge #	N	Mean	Max	Min	StdDev
3	30	2	6	3.60	1.16
9	30	2	7	4.23	1.65
7	30	2	7	4.33	1.84
8	30	3	7	4.47	1.38
6	30	1	7	4.57	1.65
4	30	1	7	4.70	1.21
1	30	3	8	4.80	1.16
2	30	3	8	5.63	1.35
10	30	3	8	5.73	1.55
BL	30	3	9	5.80	1.69
5	30	5	8	6.50	0.90

The impact of the differing value judgements for each Judge is highlighted below. Taking a sample of ten dwellings, having the 'known' condition ratings for each element (i.e. a 'known' cue profile) as shown in Table 4.

Table 4: Sample houses with known element condition ratings

	Element			
House #	Roof	Walls	Windows	Doors
1	8	3	3	4
2	4	2	3	8
3	3	8	5	2
4	5	4	8	3
5	4	5	5	6
6	2	3	3	3
7	7	5	6	2
8	6	8	7	5
9	2	4	4	7
10	3	8	5	8

By applying the regression formula (formula (1)) for each Judge for each house, the overall outcome (condition rating) can be predicted. For example, for Judge #1 and House #1, applying the regression formula gives:

$Y_{Judge\#1} = (2.69 + (0.25 \text{ x } 8) + (0.09 \text{ x } 3) + (0.11 \text{ x } 3) + (0.04 \text{ x } 4))$ $\therefore$ Predicted Outcome = 5.45

This compares with BL (i.e. the author's Baseline)

$Y_{BL} = (2.38 + (0.42 \text{ x } 8) + (0.20 \text{ x } 3) + (0.13 \text{ x } 3) + (0.05 \text{ x } 4))$ $\therefore$ Predicted Outcome = 6.93

Table 5 below shows the results for each Judge for each house after applying the regression formula. Under each row showing the predicted outcome for each Judge, another row 'Judge-BL' shows the difference for each Judge against the Baseline for each house.

Table 5: Regression applied to each house

	Judge #												
House #	1	2	3	4	5	6	7	8	9	10	BL	MAX	MIN
1	5.45	6.32	4.35	3.90	6.88	3.90	5.12	5.29	3.81	6.80	6.93	6.93	3.81
Judge-BL	(1.48)	(0.61)	(2.58)	(3.03)	(0.05)	(3.03)	(1.81)	(1.64)	(3.12)	(0.13)	0.00		
2	4.52	6.15	3.42	4.56	6.88	3.45	4.12	4.37	3.45	7.08	5.25	7.08	3.42
Judge-BL	(0.73)	0.90	(1.83)	(0.69)	1.63	(1.80)	(1.13)	(0.88)	(1.80)	1.83	0.00		
3	4.79	4.84	3.56	4.86	6.68	5.08	5.42	4.78	4.70	5.09	5.99	6.68	3.56
Judge-BL	(1.20)	(1.15)	(2.43)	(1.13)	0.69	(0.91)	(0.57)	(1.21)	(1.29)	(0.90)	0.00		
4	5.30	5.57	4.01	4.53	7.01	5.38	3.61	4.34	4.61	4.47	6.47	7.01	3.61
Judge-BL	(1.17)	(0.90)	(2.46)	(1.94)	0.54	(1.09)	(2.86)	(2.13)	(1.86)	(2.00)	0.00		
5	4.93	5.92	3.75	4.96	7.14	4.80	4.86	4.85	4.55	6.44	6.01	7.14	3.75
Judge-BL	(1.08)	(0.09)	(2.26)	(1.05)	1.13	(1.21)	(1.15)	(1.16)	(1.46)	0.43	0.00		
6	3.91	4.46	2.74	3.97	5.87	2.89	3.29	3.28	2.63	4.50	4.36	5.87	2.63
Judge-BL	(0.45)	0.10	(1.62)	(0.39)	1.51	(1.47)	(1.07)	(1.08)	(1.73)	0.14	0.00		
7	5.63	5.82	4.41	4.26	7.00	5.16	4.90	5.15	4.65	5.37	7.20	7.20	4.26
Judge-BL	(1.57)	(1.38)	(2.79)	(2.94)	(0.20)	(2.04)	(2.30)	(2.05)	(2.55)	(1.83)	0.00		
8	5.88	6.47	4.65	5.45	7.85	6.56	6.31	6.10	6.15	6.86	7.66	7.85	4.65
Judge-BL	(1.78)	(1.19)	(3.01)	(2.21)	0.19	(1.10)	(1.35)	(1.56)	(1.51)	(0.80)	0.00		
9	4.27	5.52	3.11	4.93	6.79	3.97	4.17	4.13	3.82	6.26	4.89	6.79	3.11
Judge-BL	(0.62)	0.63	(1.78)	0.04	1.90	(0.92)	(0.72)	(0.76)	(1.07)	1.37	0.00		
10	5.03	6.28	3.86	5.88	7.70	5.74	6.32	5.68	5.66	7.73	6.29	7.73	3.86
Judge-BL	(1.26)	(0.01)	(2.43)	(0.41)	1.41	(0.55)	0.03	(0.61)	(0.63)	1.44	0.00		

The identification of these differences could be utilised in several ways. One way is in the training of surveyors. For instance, if a particular surveyor appears to give too much importance to say roofs, he could be told of his tendency and corrective action taken.

Another potential utilisation of the results would be to build in particular surveyors' known policy at the time of data analysis of the survey results. This could have particular impacts on large-scale surveys (we define a large-scale survey as a sequential survey of a portfolio of properties where the total number of properties surveyed is >5000 see Kempton (2001)). The knowledge of an individuals judgement policy could be used to recalibrate the survey results. The recalibration of judgements has been offered as a way of achieving consistency in previous research (Fischhoff, 1980).

CONCLUSIONS AND FURTHER RESEARCH

The pilot study has shown that there is potential for further development of the method in the building surveying field.

The Judges were interviewed after they had completed the cue profiles. All agreed that, although the actual profiles used seemed rather contrived, they did feel that the method could be developed further. In particular, they stated that the profiles were rather bland and tedious to complete. The representation of dwellings by more interesting means such as paper-based case studies, which included photographs, or videos were particularly mentioned. As discussed previously, the use of such media would need to be considered very carefully. It was obvious, however, that more stimulating presentation methods needed to be adopted.

Further research is currently being undertaken to make the cue profiles more realistic and more interesting for participants to complete. The cue profiles are being presented in a software package. The package allows more interaction in the judgement making process, and therefore stimulate more interest.

Five of the ten Judges who took part in this study are already engaged in a follow-up study. This involves completing profiles incorporated into the software package. The results from the follow-up study can be correlated with the results of the pilot study to see whether the coefficients calculated for specific building elements, for individual surveyors, are consistent.

Another software package is also being developed to model the individual surveyor's judgement policies by the random generation of a series of dwellings, represented by a series of cue values. Given that it is possible to determine the weights that each surveyor gives to a cue, it will be possible to predict the overall condition given to a particular dwelling by an individual surveyor.

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Instructions	
Background	
	It was suggested that instead of actually visiting houses and conducting a full-scale survey, a rough idea of the overall condition of a house could be gained from the occupants descriptions of four key elements; Roof, Exterior Walls, Windows and External Doors
Method	
	A surveyor contacted occupants of 19th Century terraced houses, having slate tiled roofs, timber windows and doors, and masonry pointing brickwork (I.e. bare brick with no covering such as render etc). These houses had been identified by previous survey records. The surveyor contacted the occupant by telephone (he had no previous contact with the occupants and had never actually visited any of the houses).
Objectives	The occupant was asked a series of standard questions relating to the four key elements and potential defects to those elements. The surveyor recorded the information given by the occupant on a standard 'Telephone Record Sheet'. 30 examples of the 'Telephone Record Sheets' are reproduced in this booklet
Objectives	
	We would like to investigate the ways in which different people interpret the information contained in the 30 example 'Telephone Record Sheets'. The exercise is in no way a test of surveying/ building/ technical knowledge. It is simply to give the researcher an idea of the potential spread of interpretation.
Procedure	
1	Please complete the questionnaire
2	Please look at each example telephone record sheet and give a rating for each element and then an overall rating for the house, by circling the appropriate number. An annotated example is shown overleaf.

Figure 3: Covering note to cue profiles

RATING FOR ELEMENT	ELEMENT	DEFECTS			
	ROOF	ANY MISSING SLATES	ANY DAMAGED SLATES (SPALLING)	ANY LEAKS	
BAD 9 8 7 6 5 4 3 2 1 GOOD		NO	NO	NO	
	WALLS	ANY POINTING REQUIRED	ANY DAMAGED BRICKS (SPALLING)	ANY CRACKS NOTICED	ANY MOISTURE PENETRATION
BAD 9 8 7 6 5 4 3 2 1 GOOD		NO	YES, ABOUT 5%	NO	NO
	WINDOWS	LAST REPAINTED	LOOSE IN FRAME	ANY ROT OBSERVED	ANY MOISTURE PENETRATION
BAD 9 8 7 6 5 4 3 2 1 GOOD		5 YEARS AGO	NO	NO	NO
	EXTERNAL DOORS	LAST REPAINTED	LOOSE IN FRAME	ANY ROT OBSERVED	ANY MOISTURE PENETRATION
BAD 9 8 7 6 5 4 3 2 1 GOOD		5 YEARS AGO	YES "A BIT"	NO	WATER GETS IN UNDER DOOR

OVERALL RATING: GOOD 1 2 3 4 5 6 7 8 9 BAD

Figure 4: Example of profile presented to Judges

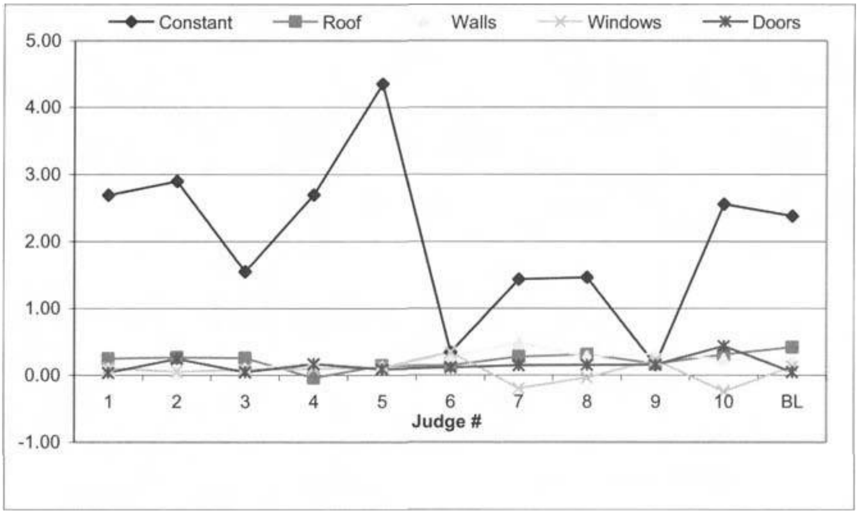

Figure 5: Judges ratings of final condition against baseline cue values

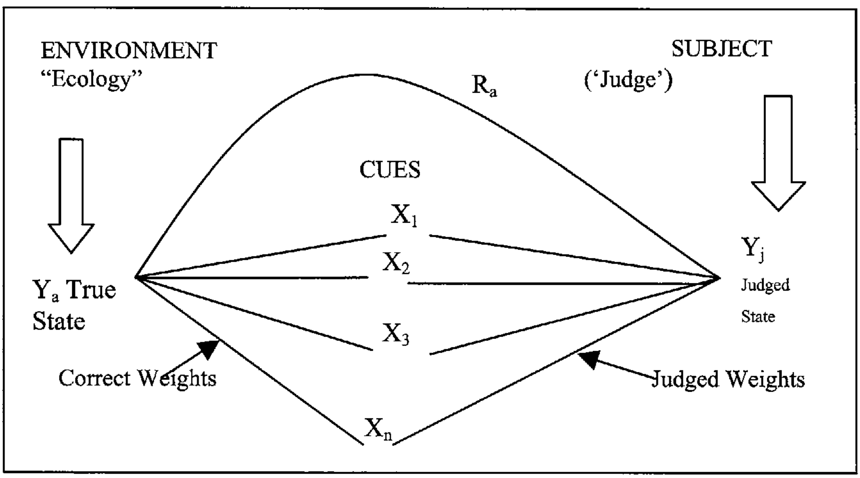

Figure 1: Classic lens model

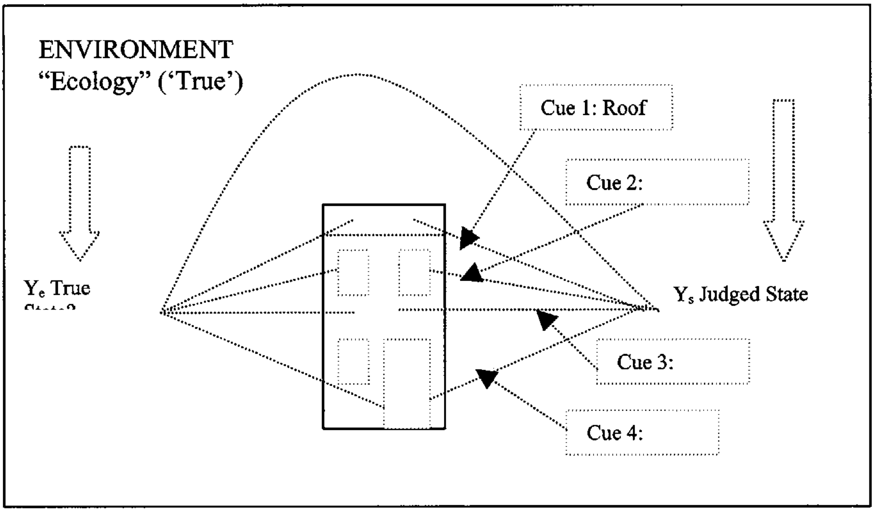

Figure 2: Lens model design for the study

MANUFACTURED HOUSING PRODUCTION PROCESS

By
Ayman Abu Hammad[1] ,Makarand Hastak[2] and Matt Syal[3]

1

INTRODUCION

Manufactured houses (MH) are single sections or multi section units; 2,3 or more sections that are fully assembled in a factory and then transported to the lots rented or owned by the owner of the MH. They are often indistinguishable from site-built houses (SBH). The production of multi section houses has increased from 28% of total manufactured home shipments in 1980 to 50% in 1996. In 1996, a multi section manufactured house cost $27.4/sq ft as compared to $54.65/sq ft for a comparable site built house (Shilling 1996).

According to the U.S. Department of Housing and Urban Development (HUD), manufactured homes amounted to 29% of single-family new residential homes over the past two decades. Over the same period, the average new manufactured home price was about 22% of the price of an average new site-built house. This makes manufactured homes an important component of the housing market and a viable single-family housing alternative (Rutherford 1989).

In 1999, manufactured homes represented 20.7% of all new single-family housing starts (Quick Facts-MHI 2001) and 21.4 million Americans (about 7.6 percent of the U.S. population) lived in 8.9 million manufactured homes (MHI 2001). Multi-section homes represented 64.7% of all industry shipments in that year, compared to single-section homes at 35.3%. In 1999, excluding land price, the average cost of a manufactured home was $43,600, compared to the average

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cost of a site-built home at $153,425. Table (1) presents cost and size comparisons for new manufactured homes and new single-family site-built homes for the years 1993-1999.

Manufactured housing retail sales were estimated at $16.3 billion in 1998. The multi-section shipments were more than single-section shipments, commanding 70.1% of the total. Annual production levels have been above 350,000 units for the late nineties, making manufactured housing the source of 25 percent of all new households in the United States (Allen 1999). In 2000, 1/6th of new single-family housing starts were manufactured homes, when the industry shipped 250,550 homes from 280 manufacturing facilities (MHI 2001).

Therefore, it is important for production managers to be able to maintain and in some cases improve the production levels at the factory to meet the increasing demand for manufactured housing.

Key words: manufactured housing, simulation, productivity, construction operations, Housing, factory layout, production line

The objective of this paper is to describe the manufactured housing production process and to describe the data collection procedure, the factory production line and the actual flow logic of the production unit that could be used to determine the system bottlenecks and to identify ways to improve the system productivity. This effort is part of an ongoing research sponsored by the National Science Foundation through the Partnership for Advancing Technology in Housing program (PATH).

PRODUCTION PROCESS

The manufactured housing production process was observed at two different factories located in northern Indiana. The factory names have not been disclosed due to reasons of confidentiality. Based on the observations at the two factories a generic model was developed for the factory layout (Table 2 and Figure 1). The generic factory layout and the data collection were designed to facilitate development of a simulation model for production analysis.

Table 1 Cost and Size Comparisons (1993-1999)

Year	1993	1994	1995	1996	1997	1998	1999
Manufactured Homes (All Homes)							
Average Sales Price	$30,500	$32,900	$35,400	$37,400	$40,400	$41,900	$43,600
Average Square Footage	1,295	1,335	1,360	1,385	1,420	1,455	1,480
Cost per Square Foot	$23.55	$24.64	$26.03	$27.00	$28.17	$28.80	$29.46
Single-Sections							
Average Sales Price	$21,900	$23,900	$26,200	$27,900	$29,400	$31,000	$31,800
Average Square Footage	1,065	1,105	1,135	1,165	1,200	1,240	1,245
Cost per Square Foot	$20.56	$21.63	$23.08	$23.94	$24.50	$25.00	$25.54
Multi-sections							
Average Sales Price	$39,600	$41,800	$44,300	$45,700	$47,300	$48,700	$50,200
Average Square Footage	1,525	1,555	1,575	1,580	1,575	1,580	1,605
Cost per Square Foot	$25.97	$26.88	$28.13	$28.92	$30.03	$30.82	$31.28
Site Built Homes							
Average Sales Price Less Land	$147700 - $36,925	$154100 - $38,525	$158700- $34,575 $124125	$166400 - $35,250	$176200 - $37,750 $13845	$181900 - $39,775	$195800 - $42,375 $15342

Price Price of Structure	$1107 75	$1155 75		$1311 50	0	$1421 25	5
Average Square Footage Cost Per Square Foot	2,095 $52.8 8	2,115 $54.6 5	2,050 $60.55	2,090 $62.7 5	2,140 $64.70	2,170 $65.5 0	2,230 $62.80

Source: U.S. Department of Commerce, Bureau of the Census (2000)

Table 2 Generic Model Station Layout

GENERICMODEL STATION LAYOUT
1- Chassis, frame- sub floor and decking (3 substations)
2- Floor Tile
3- Interior wall
4- Exterior walls
5- Roof assembly: includes Exterior finishes and Interior Finishes
6- Wheels and Axils fix & Appliances

The typical plan for a new factory is square shaped with a U-shaped assembly line layout (Figure 1) as compared to the straight-line assembly layout for older factories. The chassis frames, finished housing units and other main inventory materials are stacked outside the factory. The two factories studied for this research have a production capacity of up to 6 units / day. The double bay housing unit stays in the production line for at least two days. The ideal cycle time for the double floor house in the factory is 1.5 days.

A service road runs between the material stacks and the factory. The service road is used to move the required material from the stacks to the stations and feeders through several gates on the sides of the factory. The chassis metal frames enter through the left entrance of the factory, and then move left through the first three substations (The Floor-build sub stations).

The data collection work in addition to the factory layout will be discussed in the following sections.

PRODUCTION UNIT DESCRIPTION

The housing floor is the production unit of the system. It might form either a full house or half a house, termed as a single bay housing unit or a double bay housing unit respectively. Units of either type have several design modules. The dimensions of the module are: (20-32) feet in width, and (38-84) feet in length. Five types and sizes of floors were considered for the simulation model: 55 feet long for single bay and double bay houses, and 80 feet long for double bay houses (Table 3).

The two floors of the double bay house were designated as (a) and (b), where (a) is the floor that does not include bathrooms and kitchen and does not need to be processed at the floor tile station (station 2). Floor (b) is the second part of the house that includes kitchen and bathrooms and needs to be processed at station 2.

Table 3 Production unit- floor sizes and types

Single Bay House	*Floor Configurations*
55-feet length	Floor Single
Double Bay House	
55 feet length (Medium Houses)	55a & 55b
80 feet module length (Huge Houses)	80a & 80b

PRODUCTION LINE BREAKDOWN:

The generic assembly line of a manufactured housing factory consists of four main operations with respect to the main sub activity processed on the housing unit:

1. Floor Construction
2. Wall Construction
3. Roof Construction
4. Finishing, Appliances &Testing

Each manufactured housing factory has its own scenario for transforming the generic operations to a production line. Figure (1) shows the main six stations of a sample Factory; four of them are broken down into several substations, according to the physical setting of the factory assembly line. The station name follows the corresponding main activity.

ACTIVITY RELATIONSHIP:

Station 1: Floor-build

Substations: 1a- Chassis preparation, 1b Floor build, 1c Floor Decking:

Chassis preparation (1a) is the first station of the assembly line, where a crane lifts the chassis in order to fix the hoses and air pads to the corners of the metal chassis. Two workers process all activities in station (1a). An air pad system is used at several factories to provide temporary locomotion of the floors from station to station. When the floor reaches the end of the production line air pads are removed and a set of axles with tires is fitted to the housing unit ready for shipment outside the factory.

It was determined that the temporary mobility system using air pads is not an efficient way to move the house between the stations, because the floor occupies space and consumes processing time at the first station while the pads are being installed. In addition, whenever the unit is moved, the hoses need to be connected to the air outlets scattered alongside the stations, Figure (2).

They fix the main lines for the hot and cold water supply, the drainage and the heat ducts along the length of the floor. The drainage and water networks are prepared at the piping feeder station opposite to station 1c. The sub-activities are running in series at this station.

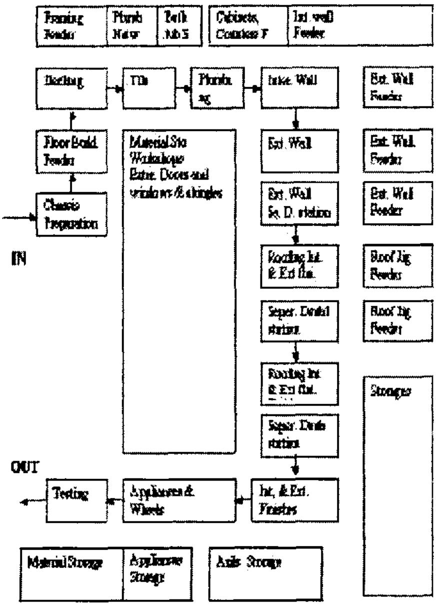
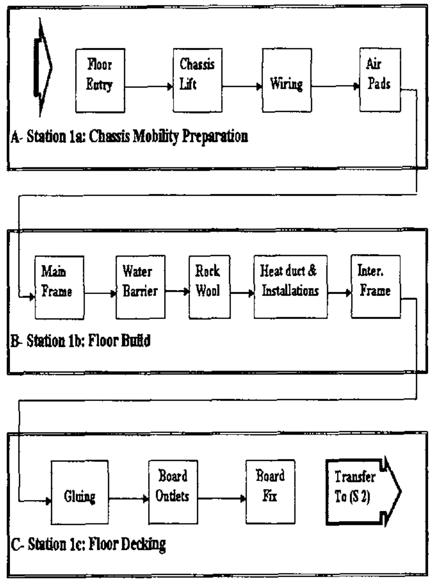


Figure 1 Sample Factory-layout



Source: By the researcher

Figure 2 Station#1: Floor build

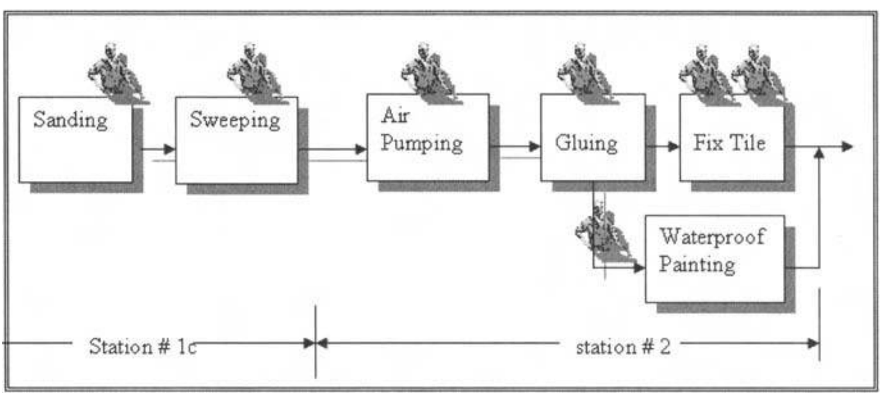
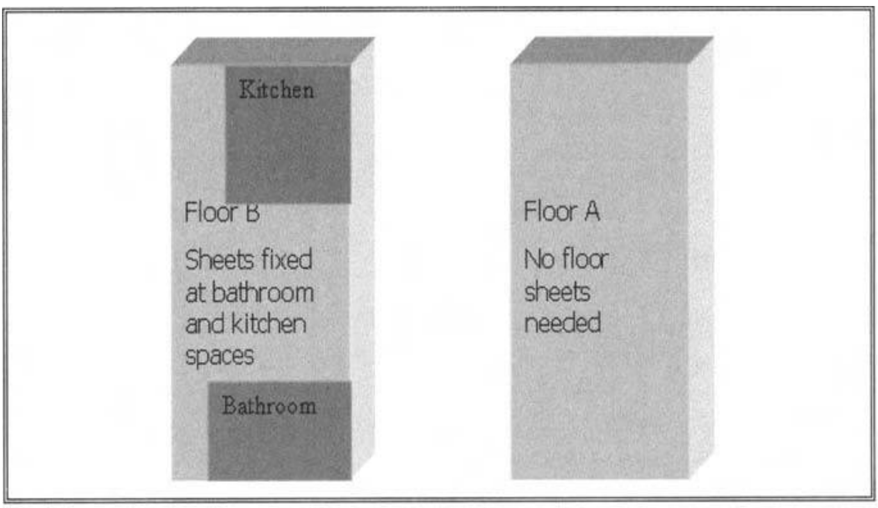


Figure 3 Station # 2: Sub Activity Relationship

At station (1c), the activities include installing and insulating the secondary heat ducts, gluing the interior main frame and fixing the floorboards after drilling the needed holes for future installations. Figure (2) illustrates the serial nature of all sub activities at station # 1.

Station 2: Floor Tile:

Floors that have kitchens and bathrooms (55b & 80b & Floor single) are processed at this station. Figure (4) shows the different floor types (a&b). Floors of type (a) are not processed at this station and wait in queue until their respective floor parts are finished and follow them to the interior wall station. One worker is in charge of floor sanding, gluing, water insulation and tile fixing. Sometimes another worker would help in these activities. Figure (3) displays the sub activity relationships at station (2).



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iFigure 4 Floor Types: a & b

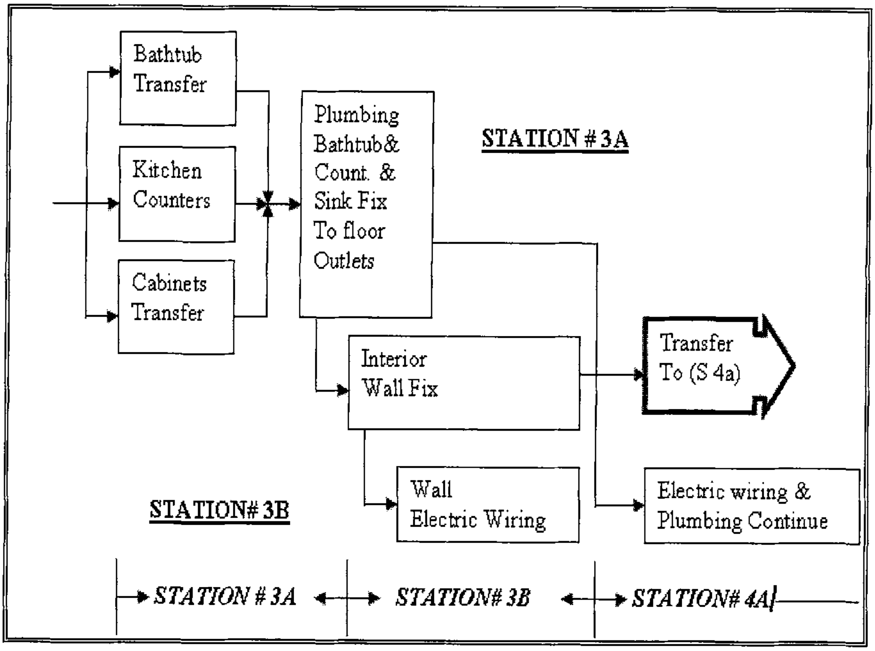


Figure 5 Station # 3: Interior Wall Station

Station 3: Interior Wall:

Substation 3a: Plumbing fixtures

After the tiling is finished, the floor moves next to the storage stacks of material and the cabinet feeder station. Two plumbers work on transferring bathtubs, sink cabinets and kitchen counters from their feeders to the floor. Then they start connecting these fixtures to the connections coming out of the floor deck.

Station 3b: Interior wall:

The main activity in this station is to fix the interior wall. After the installation of the interior wall, an electrician starts installing the interior wall wiring. Figure (5) shows the sub activity relationships at station 3.

Rework was observed during data collection causing a very long processing time. Rework at the interior wall station was due to an error in positioning the drainage outlets inside the floor.

Station 4: Exterior Wall:

At this station, the side, end, and marriage wall components that were prepared at their respective feeder stations (Figure 7), are fixed to the floor (Figure 6).

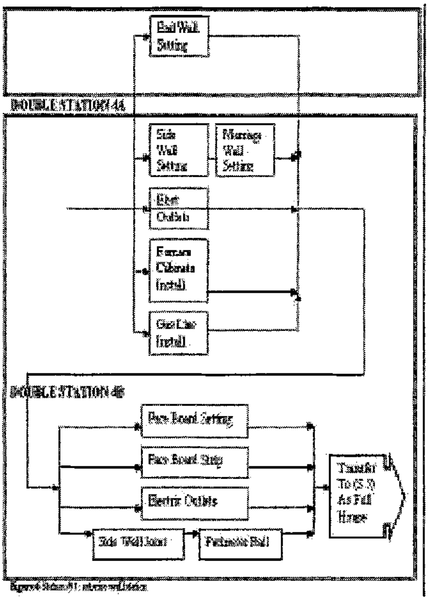


Figure 6 Station#4: Exterior wall station

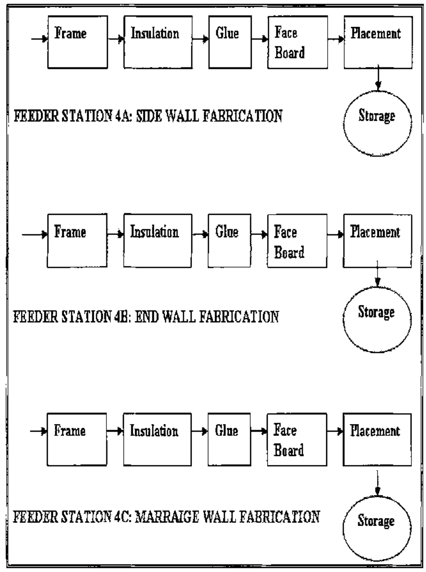


Figure 7 Feeder stations 4a, 4b & 4c

Station 4a: sidewall and marriage wall fixing:

The sidewalls are matched together temporarily for the double bay units. Two workers are in charge of fixing the different components of the exterior wall using powered screwdrivers. Two plumbers work simultaneously on fixing the bathroom and kitchen fixtures. In addition, two electricians also work on wiring the exterior walls and the main electric lines.

Station 4b: Face wallboard:

Interior face wallboards are prepared at a feeder station; one worker measures and cuts the needed boards. Another worker fixes these boards on the exterior and interior walls. An electrician works simultaneously on fixing electric switches to the face walls, see Figure (6).

The matching of the two floors happens only at station (5a), where the laborers make sure that the two roofing trusses are at the same level. Then they separate the floors again before they move them to station 5b.

Station 5: Roofing Station:

The main activity at station 5 is the roofing activity. There are three sets of activities running simultaneously at station 5: roofing activities, interior finishing activities and exterior finishing activities.

Table (4) shows the three substations of station 5 and the respective sets of activities.

The roofing station has three sub stations: 5a, 5b and 5c. The roofing mechanism for the double bay house is as follows:

Table 4 Activities at the roofing station

Substation 5a: Roofing activities: lifting roof truss, cutting edges, bolting roof truss to exterior walls Interior finishes: fixing face board, fixing electric switches, taping joints, interior face board inspection, drilling kitchen shafts in the ceiling Exterior Finishes: fixing exterior boards, bolting boards to exterior walls, fixing basic steel shingles
Substation 5b: Roofing activities: rock wool insulation, fixing roof boards Interior Finishes: cornice framing, framing interior windows and doors, fixing kitchen duct, fixing cabinet shutters, interior door and window framing Exterior Finishes: cutting openings for exterior doors and windows, bolting loose exterior boards, applying adhesive, taping, fixing exterior doors, fixing exterior windows, fixing window sidings
Substation 5c: Roofing activities: finishing the fixing of roof boards, fixing paper insulation, applying waterproofing, fixing roof shingles, fixing chimney and skylights. Interior Finishes: Fixing foam pads, fixing carpeting, fixing mirrors, fireplace…etc. Exterior Finishes: Fixing exterior wall shingles

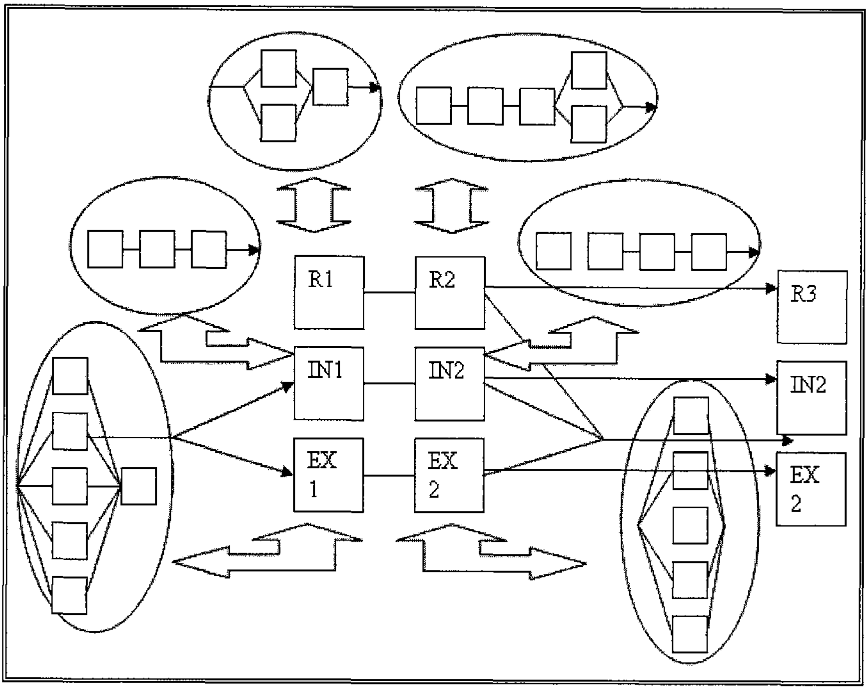


Figure 9 Station # 6: Sub Activity Relationships

At station (5a), the first roof truss section is fixed on top of floor (a) of the house. After the roof truss is fixed, the floor moves to sub station (5b) where the same floor gets insulated by one worker using a long 4 inch hose to fill the interior space of the truss with rock wool material pumped through the hose. Afterwards, floor (b) of the house enters substation (5a) and the second half of the roofing truss is temporarily attached to it. Meanwhile, the two parts of the house are attached together in order to make sure that both trusses are properly aligned. Then the second roof truss is permanently fixed to floor (b) by two workers using power screwdrivers. With both trusses fixed on top of the housing unit, the floors are detached again and floor (a) moves to station (5c) for the installation of roof boards, insulation and roof shingles, and floor (b) is sent to station (5b) to get insulated with the rock wool material. Figure (8) shows the order of the sub activities and their interrelationships at station (5).

Substation 5a: Roofing activities, Interior Finishes & Exterior finishes:

The roofing activities at this station consist of attaching the roof truss to the first floor section (a), and to match the truss of the second floor with the truss of the first floor and to fix the second floor section (b). The roofing activities consist of placing the truss. At station 5a, the roofing activities run in parallel with other two sets of activities: the interior finishes and the exterior finishes.

The interior finishes sub activity at this station consists of the following: fixing of kitchen cabinets (upper), fixing of electric switches and wallpaper joint taping. The exterior finishes sub activity at this station is the exterior wall boarding.

Substation 5b: Roofing activities, Interior Finishes & Exterior finishes:

The main roofing activity at substation 5b is to insulate the truss by filling it with rock wool material. The roof boarding activity might start either at this substation or at substation 5c. In addition, there are several other activities to be performed inside and outside the floor unit. The "Interior Finishes" sub-activities include fixing the lamps, shelves, wall-ceiling cornice, and interior doors.

The exterior finishes at substation 5b includes fixing exterior doors and windows.

Substation 5c: Roofing activities, Interior Finishes & Exterior finishes:

When the floor enters this station, the same three sets of sub activities may continue followed by other sub activities that start only at this particular station. The roofing sub activities at this station include placing the roof boards, covering the roof deck with paper, waterproof insulating, and fixing of roof shingles. The first roofing sub activity might start at the previous substation 5b if the rock wool insulation

Concerning the interior finishes, the following tasks are fulfilled: interior doors and window lintels, foam sheet secondary carpet, carpet fix, skirt fix, cabinet covers and interior doors fix. The exterior finishes sub activities are: exterior wall shingles (continuation from the previous station).

Station 6: Wheels, Appliances & Paint:

Station 6 is the last station in the production line. At this station, two workers transfer the appliances to the floor; these appliances such as the furnace, fireplace and refrigerator are stacked in storage areas alongside the station. After fixing the appliances, the factory inspectors carry out check tests for the hot and cold water and drainage network as a final inspection to make sure that everything is working well before the house is shipped out. Refer to Figure (9) for sub activity relationships at this station.

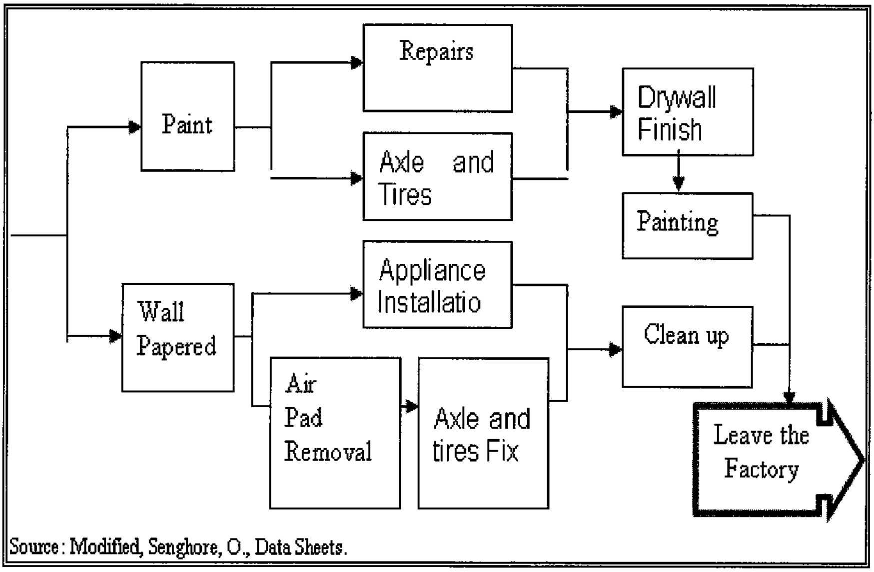
FEEDER STATIONS AND INVENTORIES:

Many inventory and feeder stations are scattered around the assembly line. The feeder stations are: Heat Duct- Main Frame Feeder- Drainage network, Cold & Hot Water Piping Feeder- Cabinets, Sinks, Kitchen Counters, Drawers & Shelves Feeders- Interior Wall Feeder- Exterior Wall Feeders: Side Wall, Marriage Wall & End Wall- Roof Jig Feeder- Interior Doors Feeder

The main storage areas are: Mainframe and interior framing storage- Bathtubs, Cabinets & Sinks- Kitchen Counters- Interior Wall- Exterior Wall- Appliances: Furnaces, refrigerators, mirrors, axles & Wheels.

DATA COLLECTION

The first step of simulating a system is to observe the system in order to understand the interrelations between the activities on one hand and to realize the process constraints and logic of the process on the other hand. The factory stations and feeder stations were mapped by first tabulating the stations and their respective activities. In the following trips, data were collected for the process time of the station/feeder station as well as for the activities running within. In addition, the time between arrivals and transfer time between stations were recorded. System constraints relating to floor movement and sequencing, crew size and material used were also observed. Modeling assumptions were set according to system constraints relating to floor type, sizes and floor sequence.



0Figure 8 Station#5: Sub activity relationship

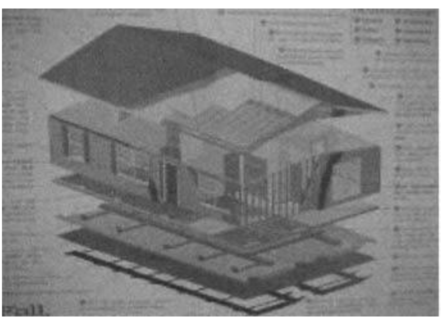
The data were collected with respect to station cycle time, sub activity duration at each station and the related feeder station. Similarly, information was gathered at each main and feeder station with respect to material used and crew composition. Ten data points were collected for each activity and sub activity. The movement of the floor between the stations defined the station cycle time, which began when the floor entered the station and ended when the floor left.

A major constraint to the data collection process was that the workers would often continue their tasks on top of the floor even though the floor was moving to the next station. It was observed that whenever activities at a certain station were finished -and there was no space available for that particular floor at the next station- the workers would leave their original station to help others at other stations. This procedure created many problems as far as data collection was concerned, since it was not possible to follow each worker leaving his station to work at other stations.

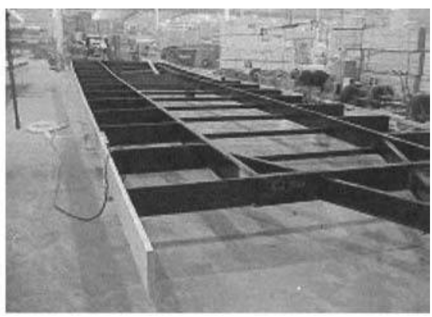
Four methods were proposed to better organize data collection. The first method was to follow the activity rather than the worker. The second method was to collect data for at least ten cycles at each station. Data collection for more cycles was not possible due to the long cycle time, and the fact that data should be collected for each distinctive floor size separately. The third method was to collect data over several one-day trips. This was not a good strategy since changes in station conditions and fluctuations in the labor force caused inconsistencies in the data. Therefore, data were collected on three consecutive day trips. The fourth method was to collect data on the production of a full house over two day trips.

The data were collected for every activity and sub activity cycle time at each station. Data were also collected for the inter arrival times, travel times between stations, labor force size and material used in each operation or activity. Data were collected from production group leaders for piping and drainage networks and assembly of interior walls at feeder stations, since it was very difficult to visually track the production process and relate it to individual floors. Another type of data was estimated on site, such as the rework durations and percentage of work rejected by inspectors.

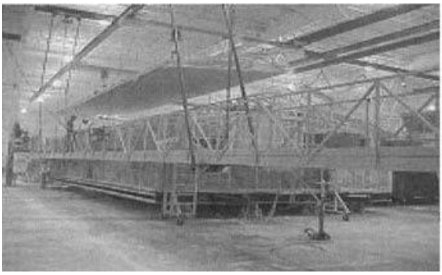
All processing times were found to be probabilistic rather than deterministic. The variation in floor sizes and the random entries from day to day according to market demand caused randomness in the observations. The processing times were measured in minutes using stopwatches. The processing time was defined as the time span from entry to the station to the end of process completion excluding the times of stoppages, rework times, and queue times. That was deliberately separated to fit into the model's logic, which models the active time separated from the queue time and the rework time. A simulation model is being developed to represent the generic factory layout and the data collected through this research to analyze the production process and to determine process bottlenecks that hinder productivity of the system.



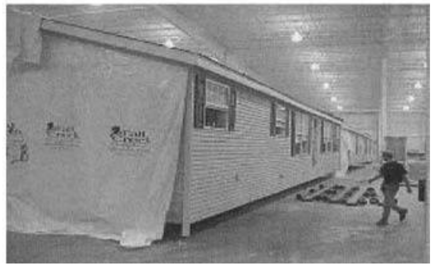
Picture (1): Manufactured House



Picture (2): Floor Chassis



Picture (3): Roofing Station



Picture (4): Finished Floor

CONCLUSION

This paper illustrated the production process of a manufactured housing factory and described the constraints in data collection that is necessary for evaluating the production process for identifying system bottlenecks. A generic factory layout was determined after studying two different manufactured housing factories in northern Indiana. The generic factory layout and the required data presented in this paper can be used for developing a simulation model that can be used effectively for identifying system productivity and process bottlenecks.

ACKNOWLEDGEMENT

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Quantification of Inefficiency in Labor Productivity-A Case Study

By Sang Yoon Han and H. Randolph Thomas

ABSTRACT

This analysis is useful for determining the factors affecting efficiency of productivity and identifying the causes of inefficiencies. Out-of-sequence, congestion, interference, work complexity, and incorrect material management can classify the categories of inefficiencies. The losses of efficiency resulting from improper management and disruptions were the greatest factor for poor performance of this activity. The result shows the activity incurred a loss of efficiency of 30%.

INTRODUCTION

This paper details how labor efficiency is affected by deviation from the normal flow of work through a case study. The case study approach focuses on the ductwork on a new municipal building project located in State College, PA. A methodology is presented to estimate the loss of labor efficiency, and loss of efficiency is calculated for each factor. The analysis is validated by comparing an inefficient work-hour profile to the chronology of events that occurred on the project.

The objective of this paper is to determine the causes of inefficiencies and quantify the impacts of inefficient management practices. The project will be described and how the data was collected and processed will be addressed. The nature of the work as it relates to the inefficient practices will also be discussed. The rules of credit were applied to calculate the daily output. The actual daily productivity will be compared with the expected productivity to determine the number of work-hours lost.

PROJECT DESCRIPTION

The case study project is a three-story municipal building in downtown State College, Pennsylvania. The structural system of the building consists of structural steel (above-ground stories), reinforced concrete (basement), and reinforced block (basement). The site area is 70,000ft^2(200ft*350ft), and the first plan area is

18,750ft^2(75ft*250ft). The crews worked directly for the prime contractor. The site staff consisted of a single project superintendent. The project will cost about $10 million, and the construction has a 16-month schedule, started in July 2000 and ends in November 2001.

Site Characteristics

The site plan of the project indicates that the site does not have enough storage area (see Figure 1). At the time the ductwork began, there were many other trades and contractors on site. The storage area was served with "the first come, first served" basis without a storage plan. Therefore, other materials like rebar, steel, and block already occupied the site. Moreover, there were congestion and interference between traffic and deliveries. The duct is a bulky material and is delivered almost every four days. It is so tough to stock the ducts outside the building, so the ducts were stocked inside the building.

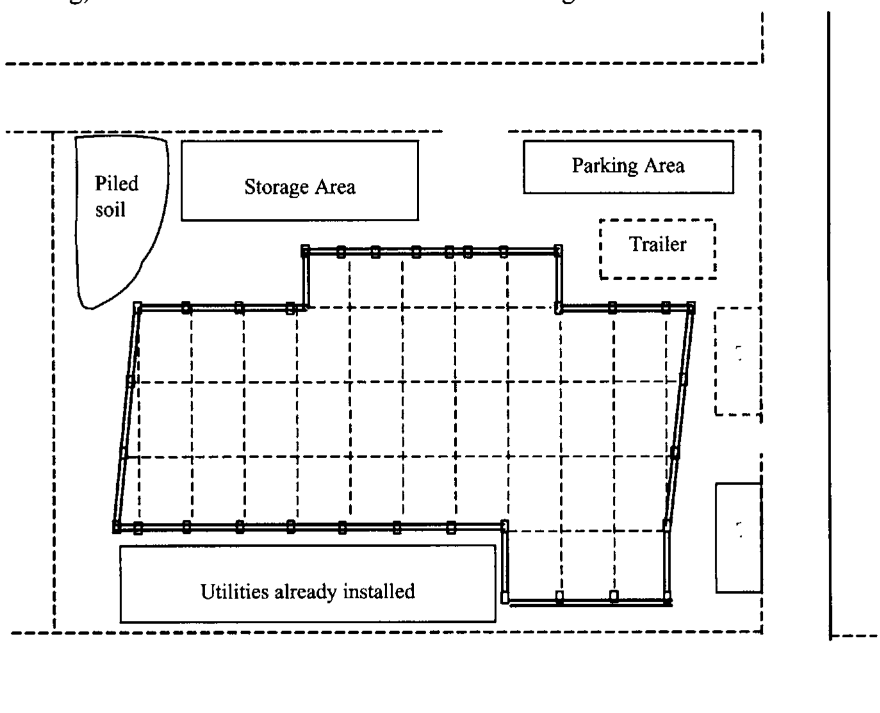


Figure 1 Site Layout

DESCRIPTION OF WORK

Scope of work

The activity studied was the ductwork, and the operation covers the entire 4 floors from basement to third floor. The activity consists of three subtasks, that is, hanger, erection, and connection. There are four major types for this work: small feeder, large feeder, branch duct, and fire damper. The ductwork is constructible, and the design dimension is standard. The components are not complex and the materials used are common in building construction. The credits and the conversion factors were given from Procedures Manual (Thomas, 2000). The quantity take off was counted with the drawings (see Table 1).

Table 1 Quantity Take off

Duct Size	Basement	1F	2F	3F	Total	Conversion Factor	Equivalent Total Quantity (ft)
x<30	1,768	2,712	2,080	1,599	8,159	0.53	4,324
30≤x≤50	56	0	22	32	110	1.00	110
x>50	0	0	0	77	77	0.66	51
Fire-damper	32	25	32	25	114	3.65	416
Total	1,824	2,712	2,102	1,708	8,346		4,901

Nature of material

Duct was made by galvanized steel forming quality with zinc quantity coating of 1.25 ounces per square foot per each side. The interior exposed non-insulated ducts must be painted grade treated white rust preventatives. Fire Damper must have a 1-1/2 hour fire protecting rating to temperature of 212 F (or 165 F as selected by local authority), and the fire dampers are installed where there are wall and floor openings, and utilizing steel sleeves.

Construction Procedures

At the beginning of the job (the first two weeks), there was enough workspace for the crew to work with. Thus, they were able to assemble 3 to 4 pieces of ducts together on the floor and used a lift to aid the installation process. However, when the job went on, interference with other crew became a critical issue. The first floor was congested with drywall. And the ductwork crew interfered with the masonry work at the basement. Therefore, they installed the ducts one piece at a time instead of using the lift.

DATA COLLECTION

The normal workhours is 6:30a.m. to 3:30p.m. on Monday through Thursday (9hours) and 6:30a.m. to 10:30a.m. on Friday (4hours), totally 40hours per week. The data was recorded in the Erection Layout sheet and Data Collection sheet. The data was collected by observation and monitoring from Monday to Friday at the end of the work. The measured quantity for each subtask was credited by rules of credit.

Then, conversion factor was used to calculate the equivalent quality (see Table 2). In this table, X is largest dimension of rectangular duct (width or depth, usually width). The actual observation for this study was conducted for 33days from February 26, 2001 to April 13, 2001.

Table 2 Conversion Factor

Type	Size Unit	Conversion Factor
Small feeder duct	30" ≤ X ≤ 50"	1.00
Large feeder duct	X > 50"	0.66
Branch duct	X < 30"	0.53
Fire damper	N/A	3.65

ANALYSIS OF DATA

Productivity Evaluation

Productivity for the ductwork is defined as the workhours per linear feet of completed duct (wh/ft). In plotting the daily productivity, it becomes abundantly clear that this project was poorly managed (see Figure 2). The following daily productivity curve shows the major problems the ductwork crew was faced with over the 33 workday data acquisition period. Almost every form of disruption was witnessed with the exceptions of rework and change orders. Congestion, out-of-sequence work, and interference with other trades are viewed as the three major reasons that lead to poor productivity on this job.

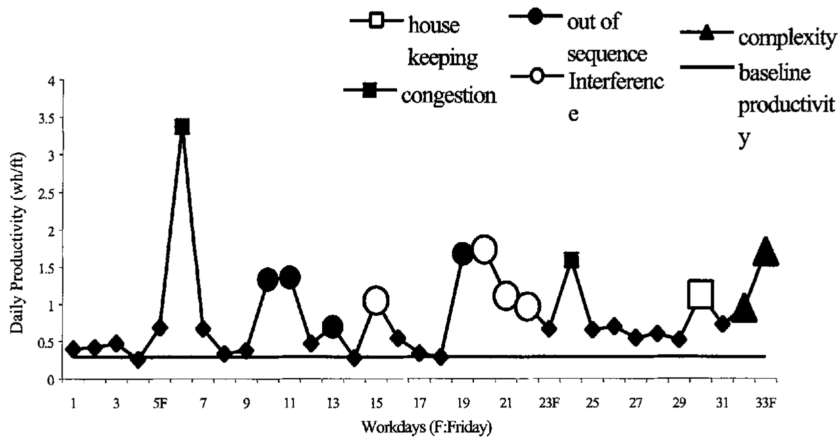


Figure 2 Daily Productivity

Table 3 Daily and Cumulative Productivity

Work day	Work hours (wh)	Equivalent Quantity (ft)	Daily Productivity (wh/ft)	Cumulative Productivity (wh/ft)	Description
1	16	40.07	0.399	0.399	
2	16	38.16	0.419	0.409	
3	16	33.39	0.479	0.430	
4	16	62.01	0.258	0.369	
5	7	10.18	0.688	0.386	
6	15	4.45	3.369	0.457	congestion in the basement
7	16	23.85	0.671	0.481	
8	16	47.70	0.335	0.454	
9	16	41.98	0.381	0.444	
10	7	5.25	1.334	0.459	out of sequence
11	16	11.77	1.359	0.492	out of sequence
12	3	6.36	0.472	0.492	
13	16	22.90	0.699	0.506	out of sequence
14	16	56.92	0.281	0.474	
15	16	15.26	1.048	0.495	interference with the other jobs
16	16	29.24	0.547	0.498	
17	16	46.72	0.342	0.484	
18	16	54.29	0.295	0.465	
19	16	9.54	1.677	0.486	out of sequence and

					delivery
20	16	9.22	1.735	0.506	interference with piping
21	16	14.31	1.118	0.521	interference with piping and cable tray
22	16	16.54	0.967	0.533	interference with heating system
23	7	10.49	0.667	0.536	congestion
24	24	15.02	1.598	0.561	congestion
25	24	36.40	0.659	0.566	
26	24	34.18	0.702	0.573	
27	24	43.48	0.552	0.572	
28	10	16.52	0.605	0.573	
29	24	46.11	0.520	0.570	
30	24	21.31	1.126	0.584	clean up for basement
31	24	32.75	0.733	0.590	
32	24	25.12	0.955	0.600	work complexity to install vertical duct
33	12	7.00	1.714	0.609	work complexity

Baseline Productivity

The baseline productivity was calculated to be 0.299 wh/ft. The baseline subset and calculations may be observed in Table 4. The baseline productivity is represented graphically along with the daily productivity in Figure 2. In analyzing the graph it is apparent that the crew was not able to perform at the desired productivity level for an extended period of time. On two occasions throughout the project the crew was able to work near the desired baseline productivity for two consecutive days. These workdays, being 8-9 and 17-18. On days 4 and 14 the crew improved productivity to reach the baseline, but where not able to continue at that level due to congestion and interference, respectively.

Table 4 Baseline Subset

Work days	Work hours	Daily quantity (feet)
4	16	62.01
8	16	47.70
14	16	56.92
17	16	46.72
18	16	54.29
Sum of subsets	80	267.64
Baseline productivity	= 80/267.64	0.299

Factors Affecting Productivity

Congestion

The first problem the crew ran into was congestion on workday 6. Congestion did not come into play again until workday 24, which was the first day an extra crewmember was introduced. Congestion and overcrowding is a management problem. The space and area in which the work is to be performed should be viewed as a resource and therefore should be planned accordingly. The time that the crew had to work in these congested areas should have been restrained by a time limit. The option of dividing up the crew into smaller work teams was not possible on this job because the crew sizes were already down to 2 - 3 members. This condition is often called stacking of trades.

Interference

The biggest problem on the project was interference with other trades. On workdays 15, 20, 21, and 22 the crew experienced major problems with multiple trades. The erected dry wall framing on the 1st floor and the erection of masonry walls in the basement hindered the crew's productivity tremendously. Instead of laying down pieces of ductwork, making connections, and then erecting long sections the crew was forced to piece-meal individual sections around previously installed piping and cable trays. The crew was also forced to maneuver sections of ductwork around framing and walls. The walls in the basement eliminated open areas that the crew could have utilized to store and lay down pieces of ductwork.

Out-of-sequence

Out-of-sequence work was performed on workdays 10, 11, 13, and 19. The availability of certain size ductwork led to this problem. The crews were forced to stop their current work and wait for the next delivery of ductwork from the shop. While the crew waited they moved and started work in another location. This forces the crew to reorganize operations and rethink the work leaving little time to do day-to-day planning. This also causes a resource problem. In jumping to and from different areas certain equipment and tools may not be readily available.

Work complexity & Housekeeping

Two other factors caused productivity problems with the crew; bad housekeeping on workday 30 and the complexity of work content on workdays 32 and 33. The crews needed a clean-up day to clear floor space and eliminate potential safety problems. This cleaning process should have been performed daily, concurrent with the erection of the ductwork. On the last two workdays of the data collection the crew began installing vertical ductwork between floors. This work is more difficult and time consuming then the erection of horizontal pieces.

Figure 3 Out-of-sequence with Masonry

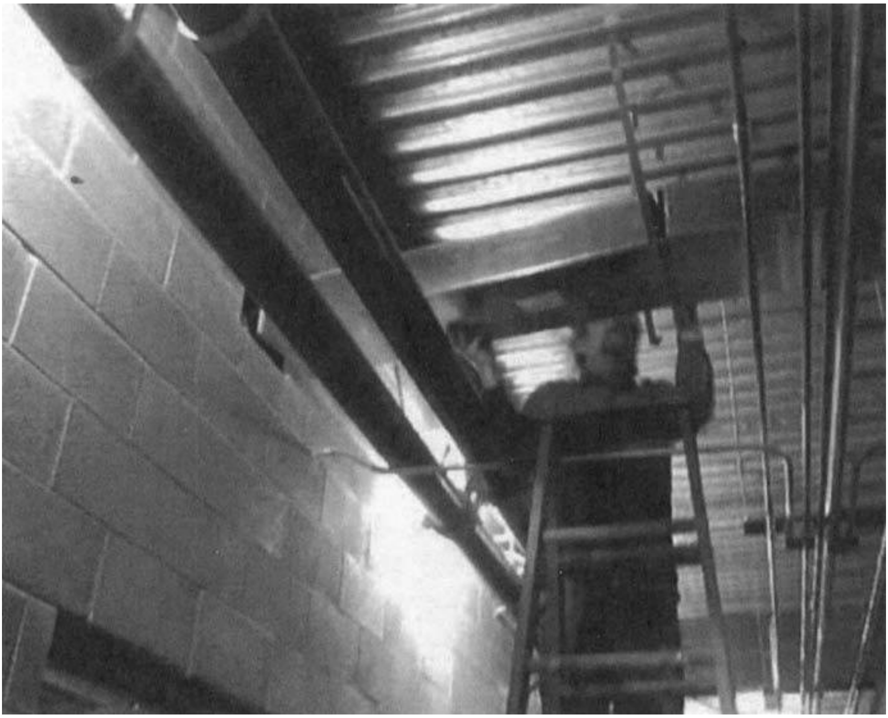


Figure 4 Interference with Piping

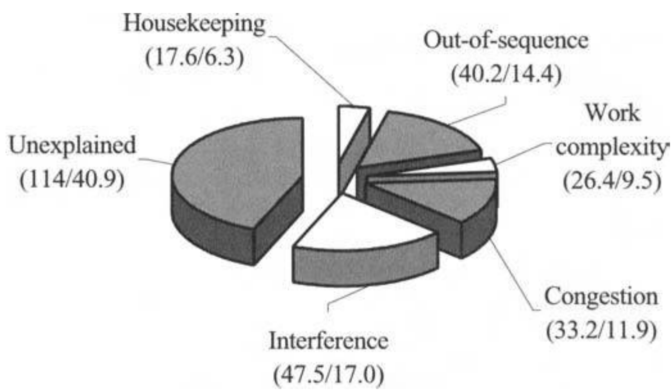
Quantification of Inefficiencies

An example for quantification of the workhours lost on the project due to the disruptions is listed in Table 5. The summary of inefficiencies including all disruptions is showed in Figure 5.

Table 5 Quantification of Workhours Lost (e.g. interference)

Workday	Daily work-hours (wh)	Daily quantity (ft)	Actual productivity (wh/ft)	Expected productivity (wh/ft)	Work-hour Loss (wh)
15	16	15.26	1.048	0.299	11.4
20	16	9.22	1.735	0.299	13.2
21	16	14.31	1.118	0.299	11.7
22	16	16.54	0.967	0.299	11.1
Total lost work-hours					47.5

Figure 5 Summaries of Inefficiencies (lost wh vs. %)



CONCLUSION

From this case study, it is clear that the performance of ductwork was significantly affected by disruptions and this project was poorly managed. The ductwork crew was faced with the major problems over the 33 workday observed. The activity resulted in a loss of efficiency with almost every disruption. Out-of-sequence, congestion, and interference with other trades are the three major reasons that lead to poor productivity on this job. This analysis is effective for identifying the factors affecting efficiency of productivity and quantifying lost workhours representing inefficiency. The result shows the activity incurred a loss of efficiency of 30%.

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DEVELOPMENT OF A FORMWORK LABOR PRODUCTIVITY FORECAST MODEL FOR THE BRAZILIAN BUILDING CONSTRUCTION

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ABSTRACT

This paper presents a labor forecast model based on the Factor Model theories as well as a very extensive site data collection and processing. The evaluation process consisted of gathering information over 616 workdays from seven construction sites. This data was statistically processed in order to generate the forecast model.

This model has being used by several Brazilian construction companies in order to help budget, plan, and control, the formwork job.

SOMMAIRE

Cet article présente une modélisation pour estimer la productivité au travail, fondée sur la théorie du Modèle des Facteurs, ainsi qu'un très important recueil et analyse de données. Cette mesure de la productivité a compris l'observation des tâches ouvrières dans de sept chantiers du Bâtiment, concernant un total de 616 *journées de travail. Les données résultantes ont été analysées pour permettre la modélisation pour estimer la productivité ouvrière.*

Cette modélisation est déjà en use par quelques entreprises brésiliennes qui ont par but une planification plus précise, un contrôle détaillé des coûts de réalisation et améliorer la vérification des tâches de coffrage.

INTRODUCTION

In order to survive in an increasingly competitive environment, it is essential for contractors to improve their construction site management skills. Labor is an important resource that needs to be managed for various reasons, either because of high cost involved or due to the strategic role it plays in terms of total success of the project.

The Brazilian projects consisted mainly (approximately 95% of the cases) of steel reinforced structures. Formwork represents 30 to 40% of the cost of these structures.

Formwork is a labor-intensive task and normally occurs in the critical phase of the project. Therefore, it is essential to understand how labor productivity varies in order to plan and execute the formwork task more efficiently.

OBJECTIVES

This paper discusses the main factors that mostly influenced formwork labor productivity. It also presents the forecasting model which was based on the extensive database provided by the site study in Brazil (the data for this study was gathered as part of a longitudinal 8-month study of construction overtime, consisting of information gathered over 616 workdays at seven different sites).

One case study is used to demonstrate the forecast model utilization; also, the actual productivity as compared to the forecast by the model and by the main budget manual used in the country.

DEFINITION

In this paper, labor productivity is measured by the following rate, as defined by THOMAS and YIAKOUMIS [1]:

$$UR_i = \frac{WH_i}{Q_i} \qquad (1)$$

Where:

UR_i = productivity for time period I;

WH_i = total workhours charged by the crew period i;

Q_i = quantity of work placed during time period i, measured in square meters of formwork..

Productivity, as defined, is called the unit rate (UR).

The UR may be calculated in a daily (dUR) or cumulative basis (cUR) (see ARAUJO [2] for more details). The baseline (bUR) is the daily UR value that represents the median value of dUR's below the cUR. Chart 1 shows the three types of UR.

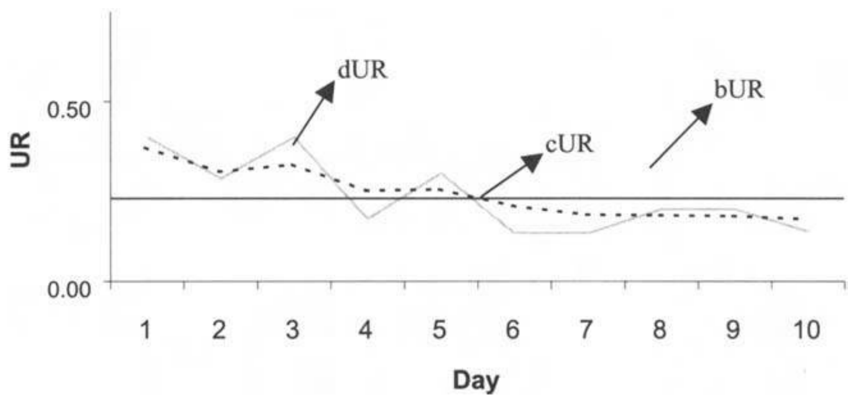


Chart 1 dUR, cUR, and bUR related to the first 10 days of generic job.

PROPOSED FORECAST MODEL

Introduction

The proposed model is based on the Factor Model ideas (THOMAS & YIAKOUMIS [1]) and was developed under the procedures proposed by SOUZA [3] and ARAUJO [2].

In order to define all the URs that characterize the job, the authors propose the following steps:

I. Calculation of bUR.

Based on most activities requiring specialized labor, the Wh (work-hour) for formwork considers all labor levels (from assistants to carpenters) as the same. Also, it considers that there is no support team.

The service involves 4 tasks: column formwork, beam formwork, slab formwork, and stair formwork and each task is calculated independently, since there are significant differences in the efforts demanded by each of them.

The rules for productivity forecast were established in three different ways:

1st – Definition of an acceptable range of productivity values.

The productivity ranges for the cases studied were obtained through a statistical analysis of the maximum, minimum, and median productivity values for each service. Any value within the range is accepted as possible productivity values for its service, although the expectations for the best or worst results involve other subjective factors.

2nd – Using the productivity range in association to a list of factors which influence productivity improvement or decline.

The knowledge of the task's contents and its environment, in association to each productivity value in the data bank, allow for the pinpointing of factors that induce productivity's improvement or descent. However, these results are not entirely accurate.

For the productivity forecast, prior comprehension of these factors and prior comprehension of positive and negative influences reduce the subjective feature in picking up values within the productivity range.

3rd – Using Math formulas to calculate the productivity.

Whenever possible, a linear regression allows a more accurate analysis of factors and productivity. Therefore, a productivity forecast is possible through a math analysis of the factors of influence.

II. Calculation of cUR

The cumulative UR involves weighting the tasks' productivity according to service quantities, as well as a revision of the potential value according to abnormalities occurrence probability. Its formula is:

$$cUR = \frac{(bUR_{column} x A_{column} + bUR_{beam} x A_{beam} + bUR_{slab} x A_{slab} + bUR_{stair} x A_{stair})}{A_{column} + A_{beam} + A_{slab} + A_{stair}} x\, c - bcoUR \quad (2)$$

Where:

bUR: baseline for the skilled team

A: area (m^2 of structure).

c-bcoUR: "cumulative to baseline" correction unit rate

The proposed values for c-bcoUR vary as shown by Figure 1. The following factors, once present in the job context, induce the adopted c-bcoUR to be higher: short time job (duration of the whole job smaller than 10 days); disruptions by other jobs; lack of materials; equipment troubles.

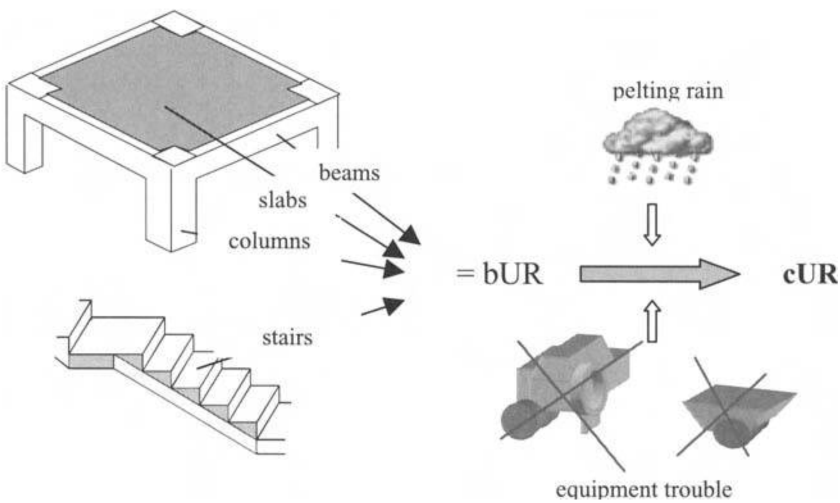


Figure 1 Steps needed to go through in order to forecast formwork labor productivity.

Factors That Influence The Baseline

Among relevant factors that influence the productivity in formwork activities, the following can be pointed out:

- Steel reinforcement concrete structure conception:
    - columns with large transversal sections result in better productivity (lower UR's), since they have larger faces;
    - higher beam length also leads to better productivity (lower UR's), since they have larger faces;
    - structural systems with too close beams increase the difficulties for pulling down the formwork, which results on worse productivity (higher UR's)
    - slabs with many beams lead to better productivity (lower UR's), since they have more subdivisions;
- Form system conception:
    - removable ties make the formwork task easier, compared to incorporated ties;
    - when the ties are predominantly located beside the column (are not crossing it) the job is easier
    - (Figure2);

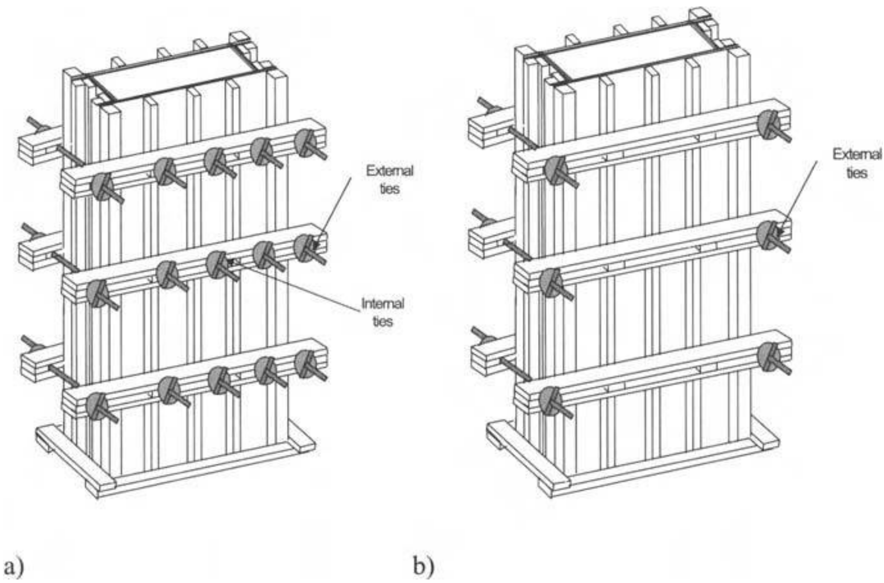


Figure 2 a) ties are predominantly located beside the column; b) ties are predominantly located crossing the column..

- whenever beam formwork demands the use of ties (Figure 3), the labor effort are bigger.

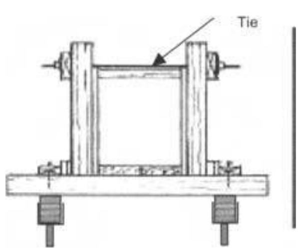


Figure 3 Beam: use of ties.

- Assembling and stripping procedures:

- it is more difficult to define the columns level by means of leveling the template for position form (Figure 4);

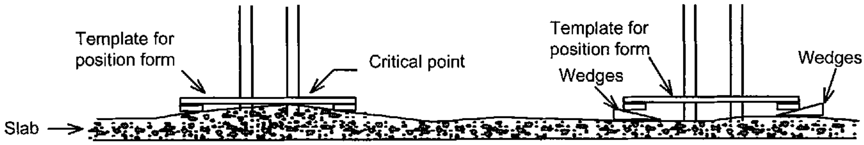
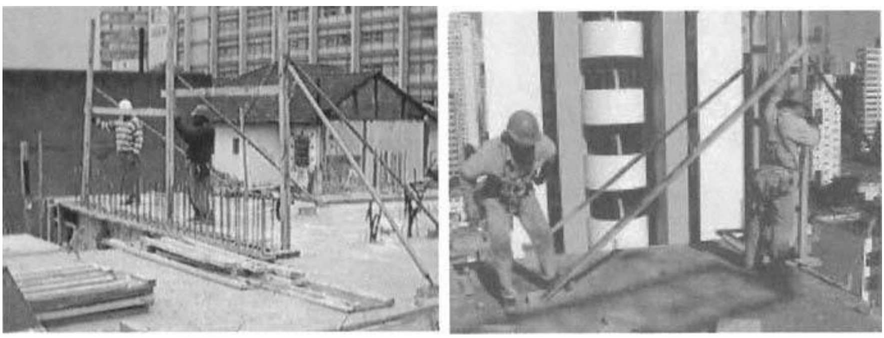


Figure 4 Columns level by means of leveling the template for position form.

- it is more difficult to plumb the whole panel (panel based plumbing) than to plumb the studs and to fix the boards to them (Figure 5);



a) b)

Figure 5 a) Examples of plumbing the studs; b) Examples of plumbing the studs.

- labor productivity improves when stair formwork is produced after the floor concrete structure is finished.

PROPOSED FORECAST PROCEDURES

bUR forecast - column

The unit rate can be calculated by the following expression:

$$bUR_{column} = 1,885 + 0,131BLE - \left(4,67SAR + 0,274BPL + 0,11TIE + 0,27LTI\right) + STR_{column} \quad (3)$$

Where:

BLE = 0 for panel has based leveling; and =1 for template for position form based leveling;

SAR= median cross-section area (in m^2);

BPL = 0 for studs based plumbing; and =1 for whole panel based plumbing;

TIE = 0 for removable ties; and = 1 for incorporated ties;

LTI = 0 for predominantly external ties; = 1 for predominantly internal ties;

STR_{column}: part of bUR referring to the column forms stripping. The proposed values for "STR" vary as shown by Table 1. One should choose higher values whenever more difficulties in stripping the panels are expected.

Table 1 "STR_{colum}" Values Variation Range.

Minimum (wh/m^2)	Median (wh/m^2)	Maximum (wh/m^2)
0.13	0.14	0.30

bUR forecast - beam

The unit rate can be calculated by the following expression:

$$bUR_{beam} = 2{,}43 - 0{,}558BL + 0{,}567TU + STR_{beam} \quad (4)$$

Where:

BL = 0 for higher beams length (> 3,00 m); and = 1 for smaller beams length;

TU = 0 for when no tie is used; and = 1 for ties utilization;

STR_{beam}: part of bUR referring to disassemble beam forms. The proposed values for "STR" vary as shown by Table 2. One should choose higher values whenever more difficulties in stripping the panels are expected.

Table 2 "STR_{beam}" Values Variation Range.

Minimum (wh/m²)	Median (wh/m²)	Maximum (wh/m²)
0.10	1.18	2.60

bUR forecast - slab

Floor structures with close slabs and beams raise difficulties in pulling down the formwork, which implies on worse productivity (higher UR's). Table 3 presents some bUR values for slab formwork in conventional structures, where slabs rely on beams, and in plain slab structures, where slabs rely directly on columns.

Table 3 Bur_{slab} Values Variation Range.

Floors	**bUR_{slab}** (wh/m²)	
Conventional structure (slabs with beams)	Minimum	0.40
	Maximum	0.96
	Median	0.69
Plain slab	Median	0.33

bUR forecast – stairs

bUR_{stairs} forecast can be based on Table 4 information.

Table 4 bur_{stair} Values Variation Range.

Stairs formwork	**bUR_{stair}** (wh/m²)	
During the floor production	Minimum	1.78
	Maximum	2.64
	Median	1.93
After the floor production	Median	1.00

cUR forecast – global

The cUR_{global} is calculated by adding a "cumulative to baseline" correction unit rate (c-bcoUR) to the bUR, as showed by the expression 3 (see item 4.1).

The proposed values for c-bcoUR vary as shown by Table 5. The following factors, once present in the job context, induce the adopted c-bcoUR to be higher: longer task cycles (longer than 2 weeks); rework; equipment breakdown; learning effect after first cycle; strikes due to workers payment problems; turnover.

Table 5 c-bcour Values Variation Range.

Minimum (wh/m^2)	Maximum (wh/m^2)
1,00	1.20

CASE STUDY

The formwork labor productivity forecast model was applied to two projects in the city of São Paulo, Brazil. Both projects were residential multi-storey buildings with steel reinforced concrete structure. Project A had a total building area of 8.649 m^2, divided among 25 floors (21 repeated). Project B had a total building area of 12.707 m^2, divided among 27 floors (22 repeated).

Table 6 describes the main job features.

Table 6 Description Of The Main Job Features.

Features		**Project A**	**Project B**
Column	Form area (m^2)	178.24	288.28
	BLE	0	0
	SAR	0 (0.32 m^2)	1 (0.18 m^2)
	BPL	0	0
	TIE	0	0
	LTI	0	0
	STR	Easy stripping	Easy stripping
Beam	Form area (m^2)	141.73	143.15
	BL	0 (3.98 ml)	1 (2.45 ml)
	TU	0	0
	STR	Easy stripping	Easy stripping
Slab	Form area (m2)	242.7	322.24
	Floor structure	Traditional	Traditional
Stair	Form area (m^2)	12.50	14.00
	Moment of accomplishment	During floor production	During floor production

Table 7 shows the forecasted cUR_{global}, using the proposed forecast method for projects A and B.

Table 7 cUR_{global} Forecasted Values

	Project A	Project B
cUR_{global} (wh/m^2)	**0.56**	**0.54**

The real cUR was evaluated by means of two on site studies. Table 8 shows de real cUR_{global}.

Table 8 cUR_{global} Real Values

	Project A	Project B
cUR_{global} (wh/m^2)	**0.52**	**0.52**

The main Brazilian budget manual (TCPO [4]) indicates 1.70 Wh/m^2 for these situations. The proposed forecast method estimates, in this case, better than the TCPO.

FINAL COMMENTS

It is very important to have a confident method to forecast productivity, in order to improve the budget process as wellconstruction management. This paper provides an approach that was based on extensive data collection, processing, and analysis. More than the forecast procedures, the paper presents definitions that have been internationally discussed, and that will allow for further comparisons between the formwork labor productivity and the reasons for higher or lower rates round the world.

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EMPLOYEE RESOURCING for a medium-large UK contractor

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ABSTRACT

Employee resourcing has an important role to play within organisations' human resource management (HRM) functions. Managed effectively, it allows employees to fulfil their career expectations whilst also meeting the organisation's succession management needs. However, the construction industry sets an extremely challenging environment for employee resourcing. Deployment decisions are usually based on the experiential assessments of line management and may not represent an optimal balance between employee needs, skills and preferences and project opportunities. This has the potential for fostering disillusionment among the employees, which consequently may contribute to increased employee turnover, and reduced trust, job satisfaction and commitment. The research reported in this paper aims to address these issues through the development of a 'Strategic Employee Resourcing Framework' (SERF). This paper discusses the outcomes of a series of interviews that assessed how the strategic HRM priorities of a medium-large construction organisation, its project specific resourcing requirements and the employees' individual preferences could be incorporated into a human resource information system (HRIS) to facilitate the strategic employee resourcing process.

INTRODUCTION

The success of a construction organisation is largely dependent upon the quality and morale of its people (Chartered Institute of Building, 1992; Clough *et al*, 2000). Human resource management (HRM) provides an influential approach to the management of people in many business sectors (Beardwell and Holden, 1997: 3). It comprises a set of practices designed to maximise organisational integration, employee commitment, flexibility and quality of work (Guest, 1987: 503). The construction industry, however, presents a challenging environment for the effective management of human resources due to the dynamic and fast changing organisational, project and skill requirements. Much of construction HRM literature has focused on the industry's need to move toward HRM-style style practices (see for example Druker and White, 1995; Druker *et al*, 1996; Maloney, 1997; Dainty *et* *al*, 2000), but little attention has been given to how to achieve this change (Tansley, 2001). This paper reports on the preliminary findings of a research project which aims to develop a strategic employee resourcing framework (SERF) to inform the efficient management of a company's human resources, taking into account the competing HRM priorities, project requirements and employee needs and preferences (Figure 1.).

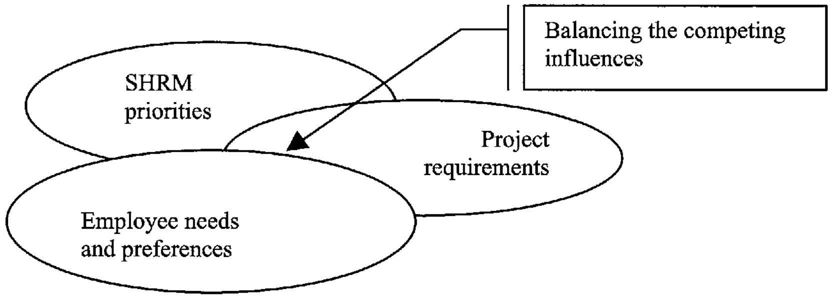

Figure 1 Integrating the competing HRM priorities, project requirements and employee preferences

EMPLOYEE RESOURCING IN CONSTRUCTION

Employee resourcing is an important function of HRM within medium-large construction companies. Figure 2. shows the major components of this function: staffing, performance and administration (Taylor, 1998: 3), together with the internal and external factors that may influence the process. This Figure provides an overall conceptual framework for discussing employee resourcing in this paper, and emphasises the complex interrelationships between the many variables affecting the resourcing process.

The main functions of HR administration, staffing and performance management within employee resourcing consist of several individual, but interrelated management activities. HR administration serves not only the resourcing process but also employee development and relations processes, focusing on the collection, storage and use of employee data (Torrington *et al*, 1991: 22). Information technology is widely used to support this function (see for example Torrington *et al*, 1991; Taylor, 1998; CIPD, 2000), although the ways and levels of practice within construction organisations vary greatly (Raiden *et al*, 2001). HRISs are the most sophisticated form of information technology specifically developed to support the HR administration. The staffing and performance management activities aim to ensure that the right numbers of employees with the right skills and competencies are in the right place at the right time. This is a balancing act in which managers are faced with taking into account the longer-term strategic considerations of HR planning while providing immediate solutions for the shorter-term operational issues, including recruitment and selection, deployment and team formation, dismissal and redundancy (Rothwell, 1995; Beardwell and Holden, 1997). Key concerns for management in construction organisations are team formation and deployment due to project-based nature of the industry (Hamilton, 1997; Cornick and Maher, 1999). Ideally, management of staffing and performance are simultaneously concerned with ensuring the best possible performance is achieved whilst facilitating employees' career progression and offering them appropriate reward for their efforts.

Employee development closely interacts with the staffing and performance activities. It is a vehicle for facilitating organisational and individual learning through training and development (Beradwell and Holden, 1997; Sisson and Storey, 2000). Systematic as well as ad-hoc development programmes help to ensure staff

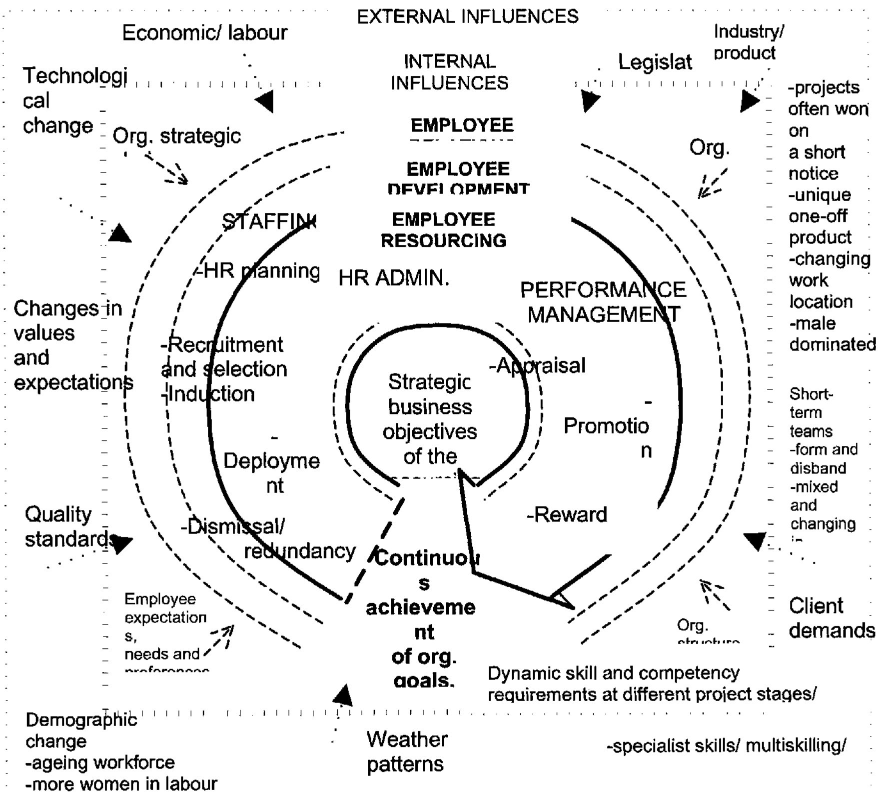

Figure 2 A conceptual model of the employee resourcing cycle in construction

have the skills required for their current roles and can develop those required for future posts. It can also work as a motivating factor: significant training indicates commitment to people and the recipients are more likely to feel valued (Sisson and Storey, 2000).

Employee relations, on the other hand, provide an overarching management philosophy or style for the management of human resources within an organisation. The traditional industrial relations issue of dealing with trades unions, together with more recent considerations of equal opportunities and managing diversity policies, all form aspects of this function.

Each of these interrelated HRM processes can influence the strengths or weaknesses of an organisation. The processes are influenced by internal and external factors, which in turn provide opportunities and threats to the organisation (Maloney, 1997).

Internal influences

The internal influences within the model (Figure 2.) are as follows:

1. *The organisation's strategic choice in terms of HRM* often affect higher level issues of employee resourcing, development and relations (Iles and Mabey, 1992: 255). In construction this may mean an organisation opting to employ staff only on fixed-term temporary contracts, invest heavily in training or devolving HRM responsibility from HR practitioners to line management (Druker and White 1995; Maloney, 1997).

2. *Organisational structure* may mean, for example, adopting a hierarchical structure or differing functional and hierarchical reporting lines (Hamilton, 1997: 99).

3. *Organisational culture* can influence the above factors as well as the HRM practices (Bate, 1992). This is more difficult to manage and control, as it is difficult to describe and measure, and varies between organisational departments and divisions.

4. *Factors central to the individual employees* within the organisation – similarly to the organisational culture, employee needs and preferences may not have such a direct or tangible effect on the HRM practices as the organisational strategic choice or structure, although they should influence the developmental stages of HRM processes. These should serve the needs of the managers in managing the employees and the needs of the employees' in involving them in the process.

Ultimately, however, all the above contribute to the strategic business objectives of employee resourcing: the continuous achievement of organisational goals at a minimum risk whilst maintaining employee commitment.

Psychological contract

Understanding the "psychological contract" is vital to understanding employee responses to the employment relationship. Rousseau (1994, cited in Hiltrop, 1996), defined the psychological contract of employment as *"the understanding people have, whether written or unwritten, regarding the commitments made between themselves and their organisation"*. Qualities central to the psychological contract include individual differences, interpersonal interaction, motivation, leadership and management style, group/team dynamics, change and empowerment (Makin *et al*, 1996). From a functional perspective, psychological contracts accomplish two tasks: they help to predict the kind of outputs which employers will get from employees, and what kind of rewards the employee will get from investing time and effort in the organisation (Hiltrop, 1996). A breach, break or violation of the psychological contract will have negative impacts on its qualities. These may include reduced trust, job satisfaction and commitment to remaining with the organisation (or indeed industry as a whole) and the withdrawal of some types of employee obligation (Robinson and Rousseau, 1994; Hiltrop, 1996; Lester and Kickul, 2001). Thus, to ensure maximum productivity, it is crucial that the individuals' preferences and expectations are taken into account throughout the resourcing process.

External influences

In addition to the factors internal to the organisation influencing the HRM processes, several factors external to the organisation affect the way HRM practices are organised. The fluid and dynamic environment of the construction industry presents a particularly problematic context for effective employee resourcing. The challenges include those that apply to construction industry specifically and those, which apply to all business sectors. Common throughout all different business sectors are: 1) technological, legislative and demographic changes; 2) changes in peoples' values and beliefs, quality standards and expectations; and 3) changes in the economic/labour markets. However, some of these, such as changes in the economic markets, may have more immediate impact on construction than other sectors. Challenges typical for the construction industry include:

- *Unique one-off product* – has to be done right the first time – uncertainty due to non-existence of prototypes (Chinowsky *et al*, 2000: 1; Clough *et al*, 2000: 2-3);

- *Projects won on short notice* – possibilities for thorough planning are limited, resourcing may need to respond to sudden changes in workload (Hillenbrandt and Canon, 1980);

- *Transient workforce* due to the nature of the product (Druker and White, 1995: 77);

- *Client pressures* demand to complete work to tight deadlines, meeting programme requirements and producing high quality – can lead to long working hours, especially near the completion of a project, staff not been released for training and development and increased stress levels (Respect for People Working Group, 2000);

- *Male dominated, macho culture/climate* – may present obstacles to the effective management of equal opportunities and managing diversity in terms of creating an accommodating atmosphere where individuals' diverse skills and competencies are utilised (Maloney, 1997: 53);

- *Short-term teams* form and disband, and are mixed and changing in composition; and *Changing skill and competency requirements* – different projects may need specialists (large) or multiskilled staff (smaller), or personnel able to work multi-site (e.g. communications departments) – the skill and competency requirements also change throughout the project duration (Clough *et al*, 1999);

- *Need for geographic mobility* due to the nature of the product presents a real resourcing problem. Almost uniquely construction workforce has to move to the location where its product is to be built; it is not possible to make the product and move it once complete as within many other business sectors.

Further challenges to the process introduce the need to balance these competing external, organisational, project and individual priorities and needs, both at strategic (long-term) and operational (short-term) levels.

Current employee resourcing practices often rely on the personal assessments of line management (Druker *et al*, 1996), which have the potential for inconsistencies, poor allocation decisions and hence, disillusioned employees through the violation of the psychological contract (Dainty *et al*, 2000). Due to the project/ organisational needs predominating the process, this has the potential to contribute to increase employee turnover, and hence, to contribute to the overall inefficiency of the industry.

The research project discussed in this paper aims to improve the current approach to employee resourcing through the development of a framework to inform the strategic resourcing of human resources within construction companies. It aims to provide a tool for balancing employee *and* organisational needs in a way which most efficiently resources individual project teams and operating divisions. It will achieve this by utilising information technology solutions.

The initial results of this research suggested that neither a centralised nor a fragmented HRM framework offers an effective paradigm, but that a balance between these two extremes may provide a better employee resourcing within construction industry (Dainty *et al*, 2000). Furthermore; a survey exploring the ways in which human resource information systems (HRISs) are used within leading contractors further suggested that in many cases these systems were used as little more than an HR database (Raiden *et al*, 2001). However, the survey showed that HRISs offer the potential to facilitate the construction industry's challenging employee resourcing operations. Thus, it is argued that using the capabilities of HRISs is likely to prove crucial in supporting the framework.

Given the highly complex and challenging environment, within which this research project seeks solutions, a preliminary set of interviews was used to establish a focus and basis for future work. These interviews present the main data on which this paper is based.

METHODOLOGY

A set of semi-structured interviews was carried out with managers and employees at various levels of an organisation in order to establish 1) current HRM strategy, policy and practice; 2) the skill requirements of the organisation; 3) the individual preferences of employees; and 4) information held on the skills and abilities of staff. The interviews consisted of the initial investigation into the organisation and its management and HRM practices. As the research focused on collecting in-depth information from the respondents and on establishing a focus for future work, approach involving only one company was found appropriate. Validation studies involving a number of organisations will follow. A semi-structured approach was adopted as this provided the discussions with an overall structure, but allowed for the interview schedules to be modified according to the nature of the individual interviewed. The research instruments were developed to explore the issues identified within the wider literature and those which emerged from previous interviews.

The initial research sample consisted of two board level directors, four HRM staff and eight senior managers responsible for HRM and deployment decision-making. During their interviews these respondents were asked to provide further informants for the research. This "snowball" sampling approach was used to acquire a sufficient number of respondents for the study. As the research progressed, care was taken to ensure an even spread of informants across the organisational divisions and checks were made to validate the sample's representativeness in terms of their age, sex, and background. Thirty employee interviews were carried out. The sample profile is illustrated in Table 1. below.

All semi-structured interviews were tape recorded and transcribed verbatim. The transcripts were coded and analysed using the NVivo software package. The conceptually labelled data was then used to model the current HRM practices and identify the compatibility and conflicts between the employee needs and priorities, and organisational management plans and HRM practices.

In addition to the qualitative interview data, quantitative data were collected via structured questionnaires. Blake and Mouton's (1985) management style questionnaire was used to assess the management style of the managers interviewed. Furthermore, an employee resourcing priority paired comparison test was developed to compare and rank order the employee's individual preferences in relation to their deployment to a project team or organisational division. These questionnaires were administered within the interviews and analysed using SPSS.

THE COMPATIBILITY AND CONFLICTS OF EMPLOYEE AND ORGANISATIONAL NEEDS

The compatibility and conflicts of employees and organisational needs are discussed below under the headings extracted from Figure 2.

External influences

The most common external influence on HRM practices mentioned by the respondents was client demands. These included increasing pressures for client satisfaction as the company aimed for repeat business, difficult or demanding clients in terms of personalities and distant locations, and indecisive clients, where changes to plans or schedules had to be approved at committees etc.

Table 1. Sample profile breakdown

Role	Approach		Sex		Age					Family Status		Base		Total
	Semi-strc.	Exploratory	Male	Female	Under 25	25 - 35	36 - 45	46 – 55	55 or over	Parent	No depend.s	Office	Site	
Director	1	2	3	-			1		2	3	-	3	-	3
Contr. Mngr	5	-	5	-			3	2		5	-	5	-	5
Chief Surveyor	1	-	1	-					1	1	-	1	-	1
Chief Estimator	1	-	1	-				1		1	-	1	-	1
HRM Staff	-	4	1	3		2	1	1		3	1	4	-	4
Comm. Mngr	1	-	1	-		1				-	1	1	-	1
Project Mngr	4	-	3	1		1	3			2	2	1	3	4
Site Manager	1	-	1	-					1	1	-	-	1	1
Site Agent	7	-	7	-		4	1		2	5	2	1	6	7
Design Co-ord.	2	-	1	1		2				-	2	-	2	2
Sen. Estimator	1	-	1	-			1			1	-	1	-	1
Senior QS	3	-	3	-		2		1		1	2	1	2	3
QS	2	-	2	-		2				1	1	1	1	2
Ass. QS	2	-	2	-	1	1				1	1	-	2	2
Engineer	4	-	4	-	2	2				-	4	-	4	4
Gen. Foreman	2	-	2	-			1	1		1	1	-	2	2
Work. Foreman	1	-	1	-				1		1	-	-	1	1
TOTAL	38	6	39	5	3	17	11	7	6	27	17	20	24	44

Managers responded to these challenges by allocating specific members of staff to projects which involved clients requiring, for example, good communication skills or specialised health and safety management skills. This resulted in some members of staff being constantly based within hazardous environments or other projects of a certain type. Managers saw this as an opportunity to build better relationships with the clients, as they were able to provide continuity and one point of contact. However, client relations also affected manager's schedules in that demanding clients often required them to attend meetings at a very short notice. One contracts manager commented: *"...I can get a call at three in the afternoon saying they need me in London by five. And you have to go."*

Employees indicated dissatisfaction with this style of management practice. Being placed on certain types of project was said to hinder their opportunities for gaining experience in varied projects and result in repetitiveness. One employee, having worked on a chemical plant with strict health and safety management routines stated: *"It is someone else's turn now, but I am stuck with it as I have been trained and doing it for the past three years"*.

A second issue was that several managerial respondents referred to difficulties in recruitment. The industry's poor image was said to affect young peoples' career decisions leading them to work for IT/law firms rather than 'traditional' construction organisations. The trend for young people to opt for full-time education instead of part-time degree programmes offered by the company was also said to adversely affect recruitment. Efforts were made to communicate with local universities, schools and colleges to secure a suitable pool of potential candidates. However, their difficulties in retaining graduates indicated possible problems in the company's practices. The current labour market presented managers with further difficulties. This led to high numbers of agency staff being employed despite the company's general aim to reduce the numbers of freelance staff. On average a 50:50 ratio applied, although attempts were made to offer long serving freelance staff permanent contracts of employment. This could lead to the employment of too many or not the right kind of staff if careful long-term human resource planning is not operated.

Employment legislation also impacted upon HRM, as staff needed particular training and skills to meet health and safety, and quality standards. Demographic changes on the other hand were not considered to be a problem as such, but rather an opportunity to diversify the workforce. Young people were said to bring in valuable new insights, although this was also said to introduce the potential for internal conflicts.

Internal influences

The company's strategic choice was to devolve HR responsibilities to line management. Although the company has a board level HR director, HRM staff were found to have little influence on the people management practices at divisional or project level. Surprisingly, the company's structure was strictly hierarchical despite the dynamic nature of the industry. The organisational culture on the other hand was described as *"open and family orientated"* with two-way communications at the heart of the operations by both, managers and employees. Although some employees referred to the existence of an internal *"old school and boy's network"*, and suggested that newcomers were *"tested"* by longer serving members of staff at site level. Only when new employees had proven themselves to their colleagues were they accepted.

With regard to employee preferences, rather mixed messages were received. Managerial respondents stated that they attempted to accommodate employee needs and preferences, especially with regard to work location. However, employee responses varied; some strongly believed managers took their opinions into account, whilst others felt their needs and preferences were continuously ignored.

Employee relations and employee development

Surprisingly, *employee relations* issues were not considered of high importance by the interview respondents. Only the Commercial Manager regarded it as an important issue, highlighting the non-existence of a dismissal procedure and the potential problems this could cause as an issue of concern.

Employee development, on the other hand, was one of the key topics discussed within many of the interviews. Both managerial and operative respondents felt the company promoted training and strongly encouraged continuous development.

Training toward professional qualifications and gaining chartered status were high priorities within management ranks. They focused on promoting staff development trough the appraisal system. (This is discussed in more detail under performance management below.) In discussing specific development programmes the managerial respondents mentioned undertaking continuous professional development (CPD), leadership and 'managing the future' programmes.

Although many employees saw the management's focus on recognised training programmes as an ideal opportunity, some disagreed with the rigid structure of these training programmes and recommended greater flexibility be added with links to the annual appraisal to be established. Apart from occasional references to guidance from senior site staff, little evidence of on-the-job training/ development was found. However, formal training courses seemed relatively frequent and varied in nature for lower level employees where they required regular updates on health and safety, first aid and machinery operations.

Overall, however, despite management efforts in investing in future through management and graduate development, employee development appeared reactive rather than proactive in meeting organisational needs.

Employee resourcing

HR administration

HR administration proved to be a complex process. Several computerised systems and manual filing mechanisms were in use. Even the simplest tasks, such as issuing pay review communications, included several members of HRM staff: information was taken from one system (payroll) and transferred to another for analysis (MS Excel) and again to a different one for the processing of the communications (MS Word). A bespoke database had been developed to hold employee records; however, this did not hold appraisal, training or pay details, which were all administered separately. Appraisals were administered manually and training plans with the Q-Pulse database at divisional level, and pay details with payroll at Plc level. When discussing the possibilities of introducing an integrated employee self-service HRIS, strong resistance was found towards the self-service functions of the system on part of the training administration manager: *"I can't have everyone messing with the system."* However, several contracts managers felt this would prove a useful function reducing their administrative workload, although they did not think this was currently necessary. It was regarded as a possible solution in the future with the business expanding.

Staffing

Staffing responsibilities seemed to have been devolved completely to line management with no input from HRM staff; as one contracts manager put it: *"It is all done here. I recommend a person to my divisional construction director; he takes it to the division MD... Maybe he then goes to HR and they look at the CVs just to check I am not looking to employ a fridge repair man..."* Indeed, all respondents strongly indicated that many of the staffing functions (recruitment, selection, induction, deployment, team formation and dismissal) were the responsibility of the contracts managers. In their weekly meetings it was decided who would be placed on which project. As there were no records of employees' performance, their skills and/or competencies, nor their qualifications or personal preferences, deployment decisions were based on the subjective assessment of the line/ contracts managers. *"I know my staff"* was a common comment from the longer serving members of the management team. Interestingly though, 3 out of the 8 senior managers, including the construction director, had been with the company for 3 years or less. They explained their initial resourcing decisions being based on the advice of their colleagues. To support the line management on recruitment issues the HR director mentioned having started investigating the possibility of introducing an 'on-site' recruitment agency.

In discussing team formation, the construction director thought it was one of the most important resourcing activities managers undertook. Surprisingly, however, the contracts managers' team selection criteria was based on 1. availability, 2. ability, and 3. personal characteristics and preferences. This suggests that they undermined the importance of team formation. The employees' views on the company's staffing practices confirmed the managerial responses.

Performance management

The formal aspects of *performance management* culminated in an annual appraisal system, which served mainly as a tool for developing a training plan for each individual employee and organisational division. Several senior managers described this system as good or very good, although a comment *"...so, that's how we do it, and then we put that away for a year again..."* would suggest that the full potential of the system was not fully exploited. Appraisals were not mentioned as being taken into account in deployment or other resourcing decisions, although they were used as a vehicle for staff promotions. The promotion procedure tended to follow the following sequence:

1. possibilities for promotion were discussed at appraisal with members of staff that the management felt were able to perform duties at a higher hierarchical level than their current posts (a few occasions were also recorded were members of staff had initiated the promotion process);

2. they were gradually given extra responsibilities over the appraisal year (June-June); and

3. formal promotions were made as a result of appraisal.

Members of staff felt that management generally encouraged and supported their career management, although no formal career management/development practices or policies were in place. However, on few occasions management seemed to have pushed employees too far with regard to promotion. An employee was mentioned as suffering from severe stress and needing considerable time off work due to work pressures which arose as a result of a promotion. Another case was of an older trades foreman who had been promoted to a post of a general foreman against his wishes. He mentioned having discussed his dissatisfaction with the promotion with his immediate contracts manager as well as the divisional operations director, but this had no impact on their decision. This suggests that the managers concerned placed considerably stronger emphasis on the organisational needs over the employee's preferences.

Although limited in its scope, the management style questionnaires supported this view revealing that managers placed considerable emphasis on the operational issues. Only two of the questionnaire respondents were categorised as 'true' people managers as a result of the questionnaire. The employee resourcing priority paired comparison test further revealed that employee needs were varied and differed according to each individual's circumstances. For example, some younger employees placed considerable importance on promotion, where employees' with families tended to prefer work-life balance over other factors. This would support the development of a system that would allow for the various and differing individual preferences be taken into account in the resourcing decision-making. Thus, the current subjective deployment practice together with operationally focused management style can not represent an optimal balance of employee and organisational needs.

The strategic business objectives of employee resourcing

Concluding the findings in the form of a SWOT analysis (strengths, weaknesses, opportunities and threats), it becomes clear that one of the company's strengths, in terms of HRM, lies in the unanimous managerial aim for good people management practice. Although employees do not feel this is always realised (which represents a weakness), this forms a positive foundation for opening future opportunities through the development of more organised HRM practices. The highly competitive business environment within which the company operates may place serious threats to this. To succeed managers need to make time from the operational issues for the initial development and implementation and ongoing maintenance of HRM policies and a HRIS. Only through systematic commitment can these help the organisation to achieve the organisational goals. Strategic planning, effective administration and communication (Smithers and Walker, 2000) together with powerful knowledge management, can contribute to minimise risk, whilst also carefully incorporating the employee voice into the decision-making. This, in turn, will contribute to the continuous achievement of organisational goals through competent, committed and satisfied workforce with fulfilled psychological contracts.

CONCLUSIONS

The findings support the conclusions of several HRM and motivational studies carried out within construction operatives and professionals. These studies have suggested improvements similar to those proposed in this study: better communications and planning on the part of the managers are required. Current employee resourcing decisions tend to focus on meeting the organisational requirements. The importance of integrating employees' needs and preferences into the process is thus neglected. The findings of the interview data discussed in this paper will be used to develop a strategic employee resourcing framework (SERF), supported by a HRIS tool, to inform the complex employee resourcing processes in construction. The framework proposed should prove an effective decision support tool for facilitating line management and HRM staff decision-making. The HRIS component should allow for effective collection, storage and use of employee data ensuring employees needs and preferences can easily be incorporated into the decision-making process. The long-term benefits could also include an enhanced image for the industry through the positive developments in its people management practices.

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CRITICAL FACTORS INFLUENCING CONSTRUCTION PRODUCTIVITY IN THAILAND

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ABSTRACT

Factors affecting construction in Thailand were disclosed in previous studies carried out by the authors, which confirmed that the construction industry in Thailand has experienced productivity problems like many other countries (Makulsawatudom and Emsley, 2001a and 2001b). The objective of this paper is to identify factors that should be focused upon, when productivity improvement is to be initiated. To do so, 34 project managers working in the construction industry in Thailand completed a structured questionnaire survey and the factors were ranked according to their perception of their levels of influence and their potential for improvement based on their overall experience in managing projects in the industry. To supplement the questionnaire data, in depth interviews were conducted with some project managers. This study is intended to create the foundation for further study of construction productivity measurement and improvement in Thailand, which aims to lead to overall productivity improvement.

THE CONSTRUCTION INDUSTRY IN THAILAND

Like many countries, the construction industry in Thailand has been dominated by a small number of large companies (>1,000 employees) and a large number of small companies (<20 employees), representing 0.2% and 68.1%, respectively of the 17512 organisations in the industry. Furthermore, these large companies have 21.5% of the market share, while the small companies, major players in the industry, only have 9.9% of the market share. Considering all organisations, 8% are involved in site preparation, 75.1% and 9.3% have their core business in civil engineering and building construction respectively, while 7.1% and 0.5% are involved with building completion and plant hire, respectively (National Statistical Office, 1999).

In respect of the workforce, the construction industry employs 1.28 million of the 33.00 million available workers, of which 80-90% are males, and has a turnover of 311,672.1 Million Baht (1£ = 64.54 Baht in July 2001), which is about 4% of GDP. During the last 8 years, industry contribution to GDP has ranged between 3 and 8% (National Statistical Office, 1999). Any improvement in construction productivity would, consequently, assist the industry and the country to make significant financial savings.

DATA COLLECTION

This study was conducted in Thailand between November and December 2000, with project managers, working at management level, as the target group. A structured questionnaire survey was selected to be the study main instrument, as it provided information quickly and cheaply. Each participant was asked to rate the factors affecting productivity on a scale from 0 (no influence) to 5 (very much influence) and to rate each factor in respect of its potential for productivity improvement on a scale from 0 (no potential) to 4 (very high potential). In addition, respondents were welcome to add and rate any further factors that they believed have an effect on construction productivity. A total of 34 questionnaires was completed. Then, before a relative importance index (RII) was applied to prioritise the severity of the factors, the raw rankings were multiplied together to produce a critical factor index (CFI). Finally, in-depth interviews were conducted with project managers.

RESPONDENTS' CHARACTERISTICS

Most respondents (97%) are male. This is not surprising as the construction industry in Thailand has traditionally been male dominated.

According to project managers interviewed, it takes 12 years for an inexperienced engineer to gain adequate experience to become a project manager. Therefore, it is reasonable that 85% of project managers have at least 11 years experience. In addition, it is not surprising that 88% of respondents are over 34 years old, as engineers in Thailand usually graduate between 22-24 years old.

During the last two decades, the majority of construction works have been public infrastructure projects. Consequently, civil works includes the maximum number of experienced respondents. However, the residential field has only started to grow in the last 8 years, so contains the least number of experienced project managers.

68% of the project managers have first degrees, with the remainder qualified at masters level and none at PhD level. Limited numbers of universities available for masters degrees, and demand for engineers in the last two decades, has encouraged new graduates into the work place. However, the relatively high number of masters graduates is due to the economic recession, providing project managers with more time to upgrade their qualifications.

Over half of the project managers (59%) have worked for their organisation for at least 6 years, and almost one third (32%) for over 10 years, reflecting that a project manager in Thailand has a fairly high commitment to his organisation.

83% of the respondents work for main contractors, while 3% are sub-contractor labour only. Like the working experience of project managers, organisations that work in the residential field include the least number of respondents, 35%, due to the same reason as discussed previously.

In respect of geographic location, Bangkok (the capital) and boundary has the most respondents (91%) and the eastern part of Thailand, which has successfully been promoted as an industrial zone during the last two decades, has the second highest number (76%). In addition, 41% of the organisations usually subcontract at least 50% of the project value to subcontractors.

In order to identify any relationship between company turnover and percentage subcontracted and geographic location of organisations, Spearman correlation coefficient was employed, which indicated that there are rank correlations between the two factors and turnover. This means the higher a company's turnover, the more jobs are subcontracted in a project, and the more geographic locations they work in.

Although a variety of sizes of company participated in the study, the mode of average annual turnover and number of permanent and temporary employees are 501-1000 Million Baht, 201-500 and over 1000 employees, respectively. This group of companies is classified as large medium organisations, according to the in-depth interviews with the project managers,

Project managers were asked to provide their opinion of employers, subordinates, working environment, level of payment and methods of construction, by ranking their opinion on a 5-point Likert scale from 5 (very good) to 1 (very poor). None of the project managers rank their present employers, subordinates, or working environment as poor or very poor. Similarly, very few of the respondents are dissatisfied with their level of payment and method of construction.

FACTORS AFFECTING PRODUCTIVITY AND THEIR POTENTIAL FOR IMPROVEMENT

Factors that influence construction productivity were gathered from a literature review of previous studies (Borcherding and Sebastian, 1980; Hanna and Heale, 1994; Kaming *et al.*, 1998; Kaming *et al.*, 1997; Olomolaiye and Ogunlana, 1989; Olomolaiye *et al.*, 1987; Zakeri *et al.*, 1996), and project managers were asked to express their opinion on the influence of the factors (from 0 to 5) and their potential for improvement (from 0 to 4). The raw rankings were multiplied together to produce a critical factor index (CFI), which were then summated and divided by 26 (the number of possible values for the CFI) to give a relative importance index (RII). Table 1 gives the factors ranked according to their RII.

Lack of material

With a RII of 0.405, lack of material was highlighted as the most critical factor affecting productivity. This is not surprising, as materials are essential for the construction process. The project managers revealed that this is mainly due to *contractors' liquidity problems*, where many contractors have insufficient finance to procure the necessary materials. In addition, when suppliers have previously experienced lack of payment, they may hold delivery until payment has been made. The project managers also said that lack of material may be due to an *incompetent project manager* who gives inadequate priority to material procurement and has insufficient knowledge of materials, including appropriate substitutes. Other causes mentioned were *imported material* and *poor co-ordination between site and office.*

In respect of its potential for improvement, although the project managers believed there is little potential, they suggested asking the client to make progress payments when materials have been delivered, implementing better sequences of work, examining materials to be used and initiating material management meetings to improve co-ordination between site and office.

Incomplete drawing

The interviewed respondents identified that incomplete drawing has a high impact on productivity, causing delays for revision or clarification of drawings and specifications. Therefore, it was ranked the second most crucial factor, with a RII of 0.373. The sole main cause of the factor is that *clients provide limited time and budget for designer* to complete the design in order to expedite the bidding process. As a result, drawings are often incomplete, unclear, impractical and contain conflicts. In respect of potential for improvement, the survey disclosed that incomplete drawing has high potential. The project managers felt that if clients provided more time and budget to designers, and also gave final drawing approval before the invitation to bid took place, and if designers spent more effort in providing details of drawings, these problems will be easily overcome.

Table 1 Critical factors influencing the construction industry

Rank	Factors	Influence ranked score						Potential ranked score					Total CFI score	RII
		0	1	2	3	4	5	0	1	2	3	4		
1	Lack of material	0	3	5	2	8	16	0	1	14	14	5	358	0.405
2	Incomplete drawing	0	2	3	10	12	7	0	1	13	14	6	330	0.373
3	Incompetent supervisors	0	3	7	7	10	7	0	2	11	14	7	329	0.372
4	Lack of tools and equipment	0	4	4	10	12	4	0	1	12	16	5	309	0.350
5	Absenteeism	0	3	11	10	8	2	0	2	10	19	3	307	0.347
6	Poor communication	0	2	9	12	4	7	0	3	11	13	7	301	0.340
7	Instruction time	0	1	8	11	9	5	0	1	11	16	6	299	0.338
8	Poor site layout	0	5	7	8	10	4	0	1	13	14	6	298	0.337
9	Inspection delay	0	0	6	14	10	4	0	1	13	19	1	294	0.333
10	Rework	0	6	5	12	7	4	0	1	12	15	6	291	0.329
11	Occasional working overtime	1	2	11	11	7	2	0	4	7	18	5	266	0.301
12	Change orders	0	2	7	13	11	1	0	5	13	13	3	265	0.300
13	Tools/equipment breakdown	0	5	8	13	6	2	0	1	13	15	5	261	0.295
14	Specification and Standardisation	1	6	9	8	7	3	0	2	11	16	5	261	0.295
15	Interference from other trades or other crew members	0	3	12	12	5	2	0	1	18	11	4	245	0.277
16	Workers turnover and changing Crewmembers	0	2	16	11	4	1	0	6	9	13	6	233	0.264
17	Scheduled working overtime	2	6	9	12	4	1	1	2	11	15	5	226	0.256
18	Safety (accidents)	0	10	12	6	1	5	0	3	10	16	5	220	0.249
19	Poor site conditions	0	5	4	13	7	5	2	6	19	6	1	207	0.234
20	Changing of foremen	2	6	12	10	2	2	0	4	11	14	5	204	0.231
21	Overcrowding	0	8	9	7	7	3	0	9	16	6	3	190	0.215
22	Shift work	7	5	7	11	3	1	5	5	7	14	3	182	0.206
23	Weather	1	5	15	9	2	2	7	11	12	4	0	114	0.129

Incompetent supervisors

This factor was ranked third in respect of its influence on construction productivity, with a RII of 0.372. Incompetent supervisors work slowly and may be responsible for defective works and inappropriate application of tools and equipment. One cause of this factor is *poor human resource management,* where inappropriate people are promoted to a supervisory role. The project managers believed that there was considerable potential for productivity improvement in respect of incompetent supervisors. By implementing employee in-house training and ensuring supervisors were correctly selected, the interviewed respondents were confident the effect of incompetent supervisors on productivity could be much reduced.

Lack of tools and equipment

Tools and equipment are important, as without them work can not be done progressively or to the required quality. This factor was ranked fourth, with a RII of 0.350 and is caused by *inadequate management*, for example, insufficient provision of tools, ignorance of maintenance programmes leading to inefficient use and the use of old and obsolete equipment and shortage of spare parts. In addition, an *incompetent project manager*, who, for example, overestimates the capacity of a machine, resulting in insufficient numbers of the machine being employed, was also mentioned. With regard to productivity improvement, the occurrence of lack of tools and equipment can be reduced by implementing preventive maintenance, as the maintenance cost is small when compared with the costs incurred when tools/equipment breakdown.

Absenteeism

Respondents ranked this factor fifth, as a crucial factor affecting the construction industry, with a RII of 0.347. Absenteeism leads to an insufficient workforce and, as a result, the schedule slips. The factor's peak impact occurs seasonally, which is usually around May to June and November to December of each year, since craftsmen, who mostly are agriculturists, have to go home to do paddy farming. Apart from these periods, International, Thai (Songkarn) and Chinese New Years are occasions when the work on many sites is almost virtually stopped for one week, because of absenteeism.

Causes of the factor are due to *part time workforces*, who come to work in the industry only when they are free from cultivation, and *irresponsible craftsmen*, who, for example, drink alcohol and gamble overnight and, accordingly, they cannot come to work the next day, or who are just absent to spend their money, after pay day. The interviewed project managers disclosed that this problem is difficult to solve and its effect can only be slightly decreased by employing defensive planning such as adding 10 extra days to the schedule if the construction period covers special occasions like Chinese New Year. Furthermore, paying salaries twice a month, rather than once, and applying stricter rules on abstention can also reduce the adverse effects of absenteeism.

Poor communication

Poor communication was ranked sixth, with a RII of 0.340. This factor allows defective works to occur due to *incompetent communication skill.* In order to overcome poor communication, the interviewed respondents advised that, instead of informal verbal communication, documentation such as work procedures, manuals, charts and guidelines should be used.

Instruction time

With a RII of 0.338, instruction time was ranked seventh. This factor causes delays and, although jobs are not stopped, they can move forward only slowly and may be crucial if jobs are on the critical path. According to interviews with the project managers, the main cause is *inadequate management,* for example, insufficient numbers of foreman employed in order to decrease expense. In addition, the interviewed respondents suggested ideas such as increasing the number of engineering officers, providing substitute field supervisors and proceeding with other jobs, when a job is stopped, which may dramatically decrease the effect of instruction time on productivity.

Poor site layout

This factor was ranked eighth, with a RII of 0.337, in respect of its significance on construction productivity. Poor site layout interrupts work flow, for example, material search difficulties, equipment transportation difficulties, or access problems. In addition, the factor may cause avoidable delays such as time lost due to, for example, too long a distance from the working area to the toilets, when 20 manhours a day could be lost if it takes 2 minutes each way per trip for 100 craftsmen for 3 trips per day. An *incompetent project manager,* who has insufficient working experience in order to sequence work properly, is the only cause of poor site layout specified by the project managers. Nevertheless, they also identified that periodical management meetings to review project progress and prepare further plans would reasonably decrease the severity of this factor.

Inspection delay

Respondents ranked this factor ninth in respect of its impact on productivity, with a RII of 0.333. Inspection delay may delay job progress, which, similar to instruction time, may be acute for jobs on the critical path. The project managers further specified that causes of inspection delay are an *incompetent project manager,* such as one who does not realise which jobs are ready to be inspected, does not prioritise jobs for inspection or does not facilitate co-operation between the contractor and inspector, and an *irresponsible inspector*, such as one who is not punctual, abuses authority and ignores jobs. Similar to lack of material, while this factor has considerable effects on productivity, it has low potential for productivity improvement. The interviewed project managers believed that this factor is largely outside their control. Their only advice was a project manager should pay special attention to jobs on the critical path.

Rework

Rework was ranked tenth, as the critical factor affecting the construction productivity, with a RII of 0.329. The more rework, the more time and cost needed for construction. Causes of rework can be attributed mainly to *incompetent craftsmen*, and *incompetent supervisors.* Insufficient working skill and knowledge of drawings are examples of an incompetent craftsman, while lack of experience, leading to deficient supervision, is an example of an incompetent supervisor. Others causes of rework advised were *change order* and *incomplete drawing.* In respect of potential for productivity improvement, the interviewed project managers suggested the provision of experienced supervisors which would overcome the two major causes of rework, incompetent craftsman and supervisor, specified above.

Other factors

Apart from those factors included in the questionnaire, two more factors were added by twelve participating project managers, with six managers adding each factor. First, *contractors' cash flow problems* was suggested with a RII of 0.366 with regard to its effect on productivity. Second, *poor project co-ordination* scored a RII of 0.346 for the same aspect. These two factors appear to be unique in the construction industry in Thailand, since the two factors are first mentioned in this research and have never been previously highlighted in any other studies.

When compared with the other factors in Table 1, contractors' cash flow problems is ranked fourth with regard to its impact on productivity. This is clearly understandable, as without sufficient financial support, necessary materials cannot be procured, and proper equipment cannot be acquired. Poor project co-ordination was also ranked high (sixth). This is not surprising, as without this, projects cannot be progressively moved forward. However, the project managers did not advise anything in respect of their productivity improvement, thus reflecting that project managers felt that these two factors are too far beyond their control.

CONCLUSION

This study has found that there have been construction productivity problems in Thailand, and disclosed the ten most significant factors affecting construction productivity in Thailand as lack of material, incomplete drawings, incompetent supervisors, lack of tools and equipment, absenteeism, poor communication, instruction time, poor site layout, inspection delay and rework. Most of these factors occur due to management malfunction, for example, incompetent project manager and poor management. This confirms the findings of previous studies which also cited that poor management is the main reason for poor construction productivity (Anon, 1981; Anon, 1974; Handa and Rivers, 1983; Malcolm *et al.*, 1987; Oloko, 1983; Strandell 1982;). However, various suggestions were raised in order to improve productivity by alleviating the effect of adverse factors.

Improvement of an organisation's productivity in Thailand should now be focused on these ten factors, since this will not only make an organisation more profitable, but also increase its chance of survival in the industry, especially as there is very high competition due to the economic crisis. If improvement in many organisations' productivity can be facilitated, overall construction productivity in Thailand will also be improved. Therefore, using this research as the foundation, future studies will concentrate on productivity improvement.

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The HIV/Aids Pandemic and the Construction Industry in sub-Saharan Africa

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PREAMBLE

With a total of just under 43 million people currently infected globally, the HIV/Aids pandemic affects most countries of the world; African countries are particularly stricken, especially those in the southern cone. The HIV/Aids situation in South Africa is examined here in some detail, it being believed that the situation there reflects that prevailing in other southern African countries. Initiatives being developed to combat HIV/Aids by the South African mining industry and others are described and it is proposed that similar initiatives be developed by the South African construction industry which, according to surveys carried out in 2000, seems to be omiss in facing up to its responsibilities.

INTRODUCTION

As is generally known by now, in 1979 and 1980 US scientists started to observe clusters of rare diseases. By 1983 the virus causing AIDS (the Acquired Immune Deficiency Syndrome), which had caused the appearance of the diseases, had been isolated and was named the Human Immunodeficiency Virus, HIV.

HIV/Aids is now a world-wide pandemic; its spread has been contained more successfully on some continents than others. Figures available at the time of writing this paper, August 2001, give the following scenario.

- Total number of people infected with HIV/Aids in 2001: 42,7 million (www.redribbon.co.za).

- Total number of people infected with HIV/Aids in 2000: 36 million
- Increase from 2000 to 2001: 18,6%
- Sub-Saharan Africa, where 580 million people live, is particularly badly affected. With 10% of the world's population, 70% of the HIV/Aids infections occur in the region. Figures are:
- Total number of sub-Saharan Africans infected: 25 million (2000)
- New infections in 1999: 3,8 million
- Number of deaths to date: 17 million, of which 3,7 million are children
- Number of orphans produced: 12 million
- Rates of adult infection in some areas: up to 40%.

To date no cure for the disease has been discovered so it is probable that the infected persons will eventually die unpleasant deaths.

The extent of the problem caused by extensive infection of a large proportion of the sub-Saharan African population only really started to be publicised in South Africa following the holding of the Durban conference on HIV/Aids in July 2000 (Economist 2000, Hawthorne 2000). Now, there is widespread publicity, moves to provide low-cost medicines to sufferers and initiatives to raise funding for affected countries in Africa.

While a belated reaction is better than none at all, there is no doubt that the pandemic will affect over the next ten years, and afterwards, all segments of sub-Saharan African society. In the following, the effects of the pandemic on the South African construction industry will be examined, its reactions to the crisis described and, following descriptions of initiatives undertaken by other industries, recommendations will be given on how to deal with the many problems that will occur.

HIV/AIDS IN SOUTHERN AFRICA

Table 1 illustrates the effects of HIV/Aids on the southern cone of Africa, showing UNAID's 1998 estimates for southern Africa. The total number infected was already 10,8 million in 1998.

Table 1. UNAIDS estimates for HIV/Aids in southern Africa in 1998

Country	Adult prevalence rate (per cent)	Number of adults & children living with HIV/Aids	Estimated number of orphans
Zimbabwe	25,8	1.500.000	360.000
Botswana	25,1	190.000	25.000
Namibia	19,9	150.000	7.300
Zambia	19,1	770.000	360.000
Swaziland	18,5	84.000	7.200
Mozambique	14,2	1.200.000	150.000
South Africa	12,9	2.900.000	180.000
Lesotho	8,4	85.000	8.500
Total/average	12	10.805.000	2.214.000

Source: Whiteside & Sunter, 2000. p. 54 (adapted)

HIV/AIDS IN SOUTH AFRICA

The situation of the pandemic in South Africa will be described in some detail; there is, by now, a reasonable amount of admittedly incomplete information available and it is believed that the situation in South Africa generally reflects that prevailing in neighbouring countries.

Whiteside and Sunter, 2000 in their book AIDS, The Challenge for South Africa, have described the evolution of HIV/Aids in South Africa and discuss its consequences. A publication produced by the Henry J. Kaiser Family Foundation, Impending Catastrophe Revisited, an Update on the HIV/Aids Epidemic in South Africa, 2001, also contains much useful information.

The evolution of the pandemic

The development of the HIV/Aids pandemic in South Africa and Kwazulu Natal, a South African province, is represented in Figure 1. A projection of the development of HIV infections in South Africa is shown in Figure 2 which shows that the maximum number of infected people is expected to reach six million in 2006.

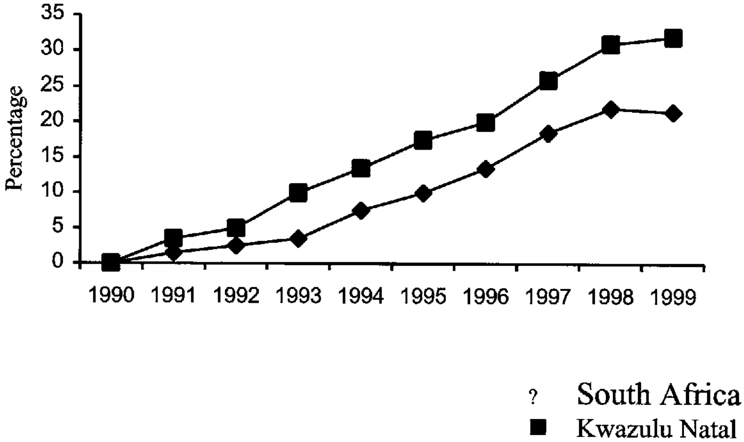

Figure 1: Evolution of HIV/Aids in South Africa and Kwazulu Natal: percentage of HIV prevalence in women attending ante-natal clinics.

Source: Whiteside and Sunter, 2000 p.51

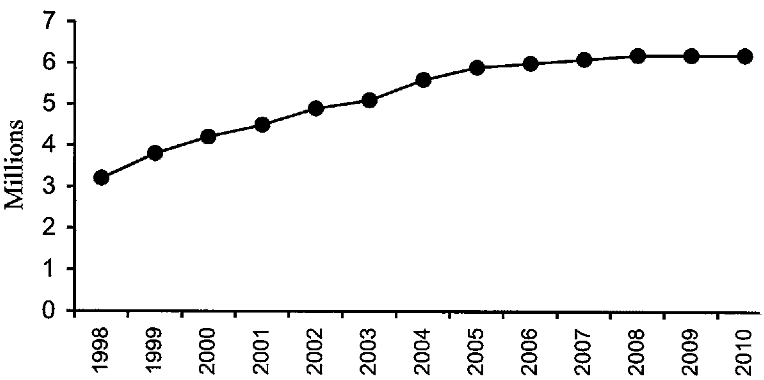

Figure 2: Projection of evolution of HIV infections in South Africa

Source: Whiteside & Sunter, 2000. p. 53

On the leading up to, and following the development of full-blown Aids, opportunistic infections tend to invade the victim's system; in South Africa TB is a particular problem: 30% of HIV-infected people contract TB and from 40% to 50% of TB sufferers are diagnosed as carrying HIV.

Distribution of HIV/Aids by trade and profession

It is believed that HIV/Aids has been rapidly spread throughout southern Africa because of the migrant labour system implemented before and during the apartheid era. Thus high rates of infection can be expected among miners, transport workers and construction workers, all of whom work for long periods away from home. In the same way, government officials and employees who are transferred around the country on a single-status basis can be expected to show higher than average rates of infection. These officials include politicians, policemen, teachers and soldiers.

HIV-positive workers per hundred workers, by industry in 2000, are estimated to be: mining 24,1; transport 18,5; construction 18,2 and agriculture 17,3 (Kusada, 2000 p. 47).

Distribution of HIV/Aids by skill level

The distribution of the infection in 2000 across the skills spectrum is, per hundred workers: highly skilled 10,2; skilled 15,5; semi-skilled and unskilled 19,9 (Kusada 2000, p. 74).

THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

Companies

The civil construction and building industry is dominated in South Africa by six large companies: Murray and Roberts, LTA-Grinaker, Group Five, Wilson Bayly Holmes, Basil Read and Concor. All of these companies are active in southern Africa and many are penetrating into other African countries and further afield. This group of six companies is complemented by a further 302 companies registered with the Federation of Civil Engineering Contractors of which 99 are emerging contractors and a further 971 are registered with the Master Builders Association; these are small and medium enterprises active mainly in building works throughout South Africa.

Attitudes to the pandemic in the South African construction industry

During 2000 L. Kusada surveyed the attitude of South African construction companies to the HIV/Aids pandemic (Kusada 2000). Of the 35 companies contacted, 12 agreed to participate in the survey. A similar survey was simultaneously carried out by correspondence of 12 Zimbabwean construction companies.

The results confirm the authors' impressions of public and government attitudes prevailing in South Africa prior to the July 2000 Durban conference on HIV/Aids; many companies and entities seemed to be in denial, indifferent to, or ignorant of the extent of the problem (Economist, 2001). Fortunately, attitudes are changing, but slowly.

In the parallel, and less thorough, survey of the attitudes held in the Zimbabwean construction industry twenty companies were invited to participate in the survey; of these, six larger and six smaller companies responded. It is apparent from the survey that attitudes in the Zimbabwean construction industry are more enlightened, possibly because the evolution of the pandemic is at a more advanced stage.

Perceptions and attitudes to the HIV/Aids pandemic in the South African construction industry

OBK Basiami carried out a survey in 2000 of perceptions and attitudes to the pandemic held by management and by lower management and supervisory staff in the South African construction industry. (Basiami, 2000).

He obtained a 100% response from the ten larger construction companies approached and 22 responses to the 30 questionnaires sent to members of middle management and sub-contractors.

The results of the survey confirm the attitudes registered in Kusada's survey.

EFFECTS OF THE HIV/AIDS PANDEMIC ON PRODUCTIVITY IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

The construction industry's productivity may be affected by external and internal factors; the internal factors can be divided into direct and indirect items.

External factors

The first HIV infections were identified in the early 1990's; with an eight-year incubation period, full-blown AIDS probably started to appear in 1998 (it is stated 'probably' because AIDS is not a notifiable disease and there are no reliable records available of its spread.)

As the disease takes a grip on the country it is expected that the efficiency of government-run support industries, such as the electricity, telephone, transport and postal sectors will be affected (Fine, 2001). The non-functioning of the secondary and tertiary education industry, police and private security sectors will also negatively affect the construction industry. It is expected that the already-high crime rate in South Africa could increase unless steps are taken to accommodate the expected Aids orphans who otherwise would become street children and then criminals.

Internal factors: direct items

The following lists some of the items which could lead directly to decrease in productivity within the construction industry:

- Absenteeism: increasing because of the ill health experienced by employees. Workers also take time off to care for their families (these demands are felt especially by women) and to attend funerals.
- The morale of the workforce sags
- Sick workers are less productive at work. They cannot carry out the more demanding physical jobs
- Accidents: They occur more frequently because of fatigue in the work-place
- Employees who die or retire on medical grounds have to be replaced. Their replacements may be by less skilled and experienced people who therefore may require training.
- The average age and experience of workers fall as the proportion of new and younger recruits rises.
- Employers increase the size of their workforce to provide for deaths during apprenticeship and because of absenteeism generally
- As skilled workers become scarcer, wages have to be increased for the limited pool available
- The communities in the neighbourhood of a business start needing more support to weather the crisis.
- The costs of health care, medical aid, and hospitalisation rise

(Source: Whiteside and Sunter, 2000)

Factors which indirectly affect the turnover of the construction industry, particularly the smaller firms are:

- Sales: Growth in the volume of sales, and in some cases the actual volume of sales itself, declines as the market shrinks because of consumer sickness and death (Bifsa, 2000).

Table 2 shows the distribution of increased labour costs by category, where it is seen that absenteeism is the largest contributing factor:

Table 2. Increased labour costs due to HIV/Aids

HIV absenteeism	37%
Burial	16%
AIDS absenteeism	15%
Recruitment	9%
Training	7%
Funeral attendance	6%
Health care	5%
Labour turnover	5%
	100%

Source: Whiteside and Sunter, 2000 p. 101

Employee benefits, which in 1995 represented 7% of wages and salaries, are expected to increase to 18% by 2010. The benefits comprise disability pension, spouse's pension and lump sum at death (Whiteside & Sunter 2000 p. 102). See also McFarlane (2001) for more details on costing.

INITIATIVES BY OTHER SOUTH AFRICAN INDUSTRIES

While the construction industry has been relatively passive in developing policies to deal with HIV/Aids a number of other South African industries have started to develop initiatives, which could be usefully emulated by the local construction industry.

Goldfields is a South African gold-mining company which employs 48 000 workers of whom 26,7% are infected with HIV. (Bailey 2001). The company has developed a programme which consists of supplying tested condoms to the prostitutes who service the mine's workforce and subjecting the workers to a barrage of training programmes on HIV/Aids prevention.

BHP Billiton is a mining company which has abolished the traditional hostel system where single status workers were serviced by prostitutes and has promoted a housing policy which promotes normal family life for all employees. The company promotes HIV-awareness programmes and managed health-care schemes to cover all employee ailments. (Fontyn, 2001)

Eskom is South Africa's electricity producer and distributor and employs 33 000 people. The company's programme covers basic education, counselling, dispensing of condoms and voluntary testing. The company feels that the strong point of its programme is the use of 1 000 peer-educators drawn from the workforce. The company estimates that less than 10% of the work force is now infected. (Innocenti 2001)

Daimler-Chrysler, South Africa is an automotive company which has launched a HIV/Aids workplace strategy which involves spending R6 million (US$ 750 000) in its first phase. Its strategy includes local education campaigns, the training of doctors and health workers, the provision of drugs and the monitoring of their application, and the training of 130 peer educators.

Testing of about 11 000 South African National Defence Force troops revealed that about 17% were infected with HIV. Medical staff are being trained to care for HIV positive soldiers and the army hopes to train a minimum of 6 000 peer educators. (Beresford, 2001)

RECOMMENDATIONS FOR THE CONSTRUCTION INDUSTRY

The South African construction industry, compared to other industries, seems to be apathetic with relation to the HIV/Aids pandemic. This is probably because unskilled and semi-skilled labour is hired on a contract basis and is increasingly being hired via subcontractors.

The recently published King Report on corporate governance emphasises however, among other things, the need for South African companies to increase their level of social responsibility. This reinforces the authors' feeling that South African construction companies should adopt the HIV-prevention and Aids relief initiatives already being implemented by other industrial sectors, such as the mining industry.

Before these actions are listed, other initiatives are necessary to be implemented by government which would facilitate the work of the construction and other industries. These initiatives include:

- Sanctioning HIV testing within companies

- Establishing AIDS as a notifiable disease
- Regulating the profession of prostitution
- Negotiating with Brazil, India or Thailand the importation of low-cost generic HIV/Aids drugs, which would be made available for distribution by the private sector.

Industry's actions would consist of each company engaging competent health professionals to manage the company's HIV/Aids programme.

The programme would comprise:

- a massive educational effort implemented by peers
- voluntary testing of employees for HIV
- distribution of condoms
- testing for Aids
- testing for TB, malaria and other opportunistic diseases
- provision and supervision of the use of AIDS drugs
- forwarding of sufferers from TB and other opportunistic infections to appropriate clinics and hospitals

In compensation for this work, it is proposed that the companies concerned would receive generous tax concessions.

CONCLUSIONS

The general conclusions reached are the following:

- experience gained in South Africa on the HIV/Aids pandemic can be applied to neighbouring countries which are similarly affected.
- just before and following the July 2000 Durban conference the problem of the HIV/Aids pandemic in Africa was widely publicised. Publicity continues in 2001 but there is a danger of Aids-fatigue setting in.

- a number of large South African companies have started to implement serious HIV/Aids prevention initiatives and are being assisted by management consultants and insurance companies.
- the construction industry seems to be omiss in this respect
- estimates have been made of the cost of prevention initiatives and there is a body of work which compares the cost of prevention with the cost of treatment of sick workers
- HIV infections continue to increase

RECOMMENDATIONS FOR FURTHER RESEARCH

Further areas of research include:

- Carrying out research into the HIV/Aids policies of the larger construction companies, as they develop them
- Examining how Small and Medium Enterprises (SME's) could manage a prevention programme
- Examining how to motivate changes in the behaviour of industry employees.
- Preparation of cost-benefit analyses comparing the cost of medical support to infected employees with the benefit of prolonging their production capacity.

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