Management of Technology
Key Success Factors for Innovation and Sustainable Development

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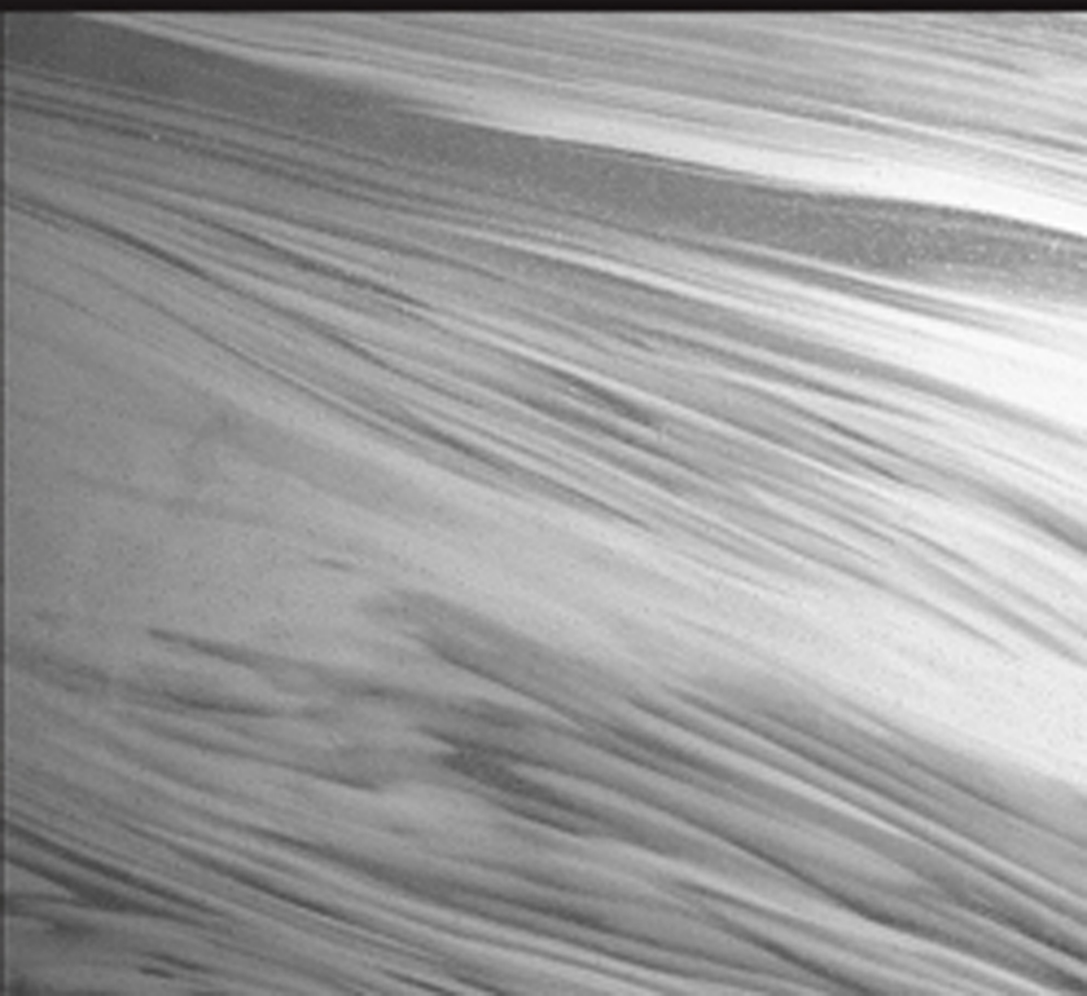

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Selected Papers from the Twelfth International Conference on Management of Technology

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Key Success Factors for Innovation and Sustainable Development

Selected Papers from the Twelfth International Conference on Management of Technology

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PREFACE

Vincent Boly, INPL-ERPI, Nancy, France[*]
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The 12th International Conference of the International Association for Management of Technology (IAMOT) held in March 2002 in Nancy, France, focused on "Innovation and Sustainable Development". These conferences present a unique opportunity to exchange best practices while debating new concepts of managing innovation, technology and R&D. IAMOT remains a major scientific forum where leading researchers and practitioners meet. More than 480 abstracts were received during the call-for-papers, of which 305 were submitted as full papers reviewed and accepted for presentation. Some of the original conference papers have since been published in international journals indicating the dynamism and the scientific quality of IAMOT. This book represents a selection of the best contributions presented in Nancy. It is also the output of the long term partnership between IAMOT and Elsevier and Pergamon Publishing.

A major concern for all researchers focusing on Technology Management is Sustainable Development. IAMOT papers in this research field represent an important contribution within the scientific international community. This was influenced by several factors. First, many academic laboratories directed their attention toward a better understanding of new product development processes and proposed new methodologies

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to improve time to market, launching success, technical quality and profitability. Management approaches, data treatment methods and decision making methodologies are being widely studied. Complexity, integration of qualitative and quantitative variables and uncertainty are among others key concepts of these investigations. As a consequence, many IAMOT members based the early phases of development projects on sustainable objectives. As a matter of fact the question became: how to take sustainable constraints into account before launching a new technology? Researchers state that the design process of a new technology influences its future impact on the environment and they recommend new project management approaches aiming at a reduction of risks with emphasis on quality of life.

Second, the technology management literature is mostly concerned with the multivariable impacts of technology on our industrial world. Research themes include: economic policy facilitating innovation, interaction between employment and new technology, international competition, technology emergence and industrial sectors reorganisations. Hence, via this involvement it is possible to gain access to a wealth of concepts required to analyse long term, cultural and ethical impact of technology on each level of our world.

Third, many academic laboratories focus on strategy. This includes subjects as: technological forecasting, comparison of industrial strategies in the field of technological development and decision making to optimise technological resources. Sustainable development implies an evolution in the criteria integrated in strategic objectives of nations or companies. As a consequence the notion of sustainable development represents an enrichment of previous programs still exposed during IAMOT meetings.

The selection of the bests from many excellent papers has been a difficult task but a decision was necessary for the production of this book. The contributions are arranged according the three following chapters:

- Rewarded papers: best paper and best student papers,
- Sustainable Management of Knowledge and Competencies,
- Innovation- New Product and Technology Development.

In the first section Terra et al. discuss the important differences between Information Management (IM) and Knowledge Management (KM). Note that sustainable development required data and knowledge about past or long term impact of technology improvement on our world. As a consequence the problem of KM and IM in technological industries remains a key theme. One major aspect highlighted by the authors is the variability of learning processes in companies. N'Gassa et al. focus on a complementary aspect: decision making. They propose a new modelling approach based on Unified Modelling Language. Their basic hypotheses are relevant with those of Petteri et al. studying decision making in technological investment selection.

The second section is composed of articles addressing various issues of knowledge management (KM).

As an introduction, Kuivalainen et al. present phenomenons observed in small knowledge intensive firms and question the correlation between KM and performance level.

Considering the management of explicit knowledge, three functions are generally taken in account: internal and external collect (technological forecasting), then extraction, modelling and classification, and finally reuse. Sugasawa et al. consider the sources of knowledge and analyse the strengths and weaknesses of technical intelligence in Japan. Jolly presents his views on China through an original study of Sino-foreign joint ventures. Revel analyses the role of Total Quality Management in the reuse of knowledge within a panel of seven French companies. The case of virtual projects where most of the team members are geographically dispersed is more specific. KM appears to be particularly challenging in Petit et al. opinion. Farukh et al. point out the problems of knowledge transfer through service interfaces.

Note that Cataldo et al. concentrate on tacit knowledge and therefore their main theme is different from those of researcher focusing on explicit knowledge.

Knowledge and information constitute part of the resources shared by companied within cluster or industrial networks. Rawat considers the case of high technology development areas of Bangalore. The paper by Buys et al. analyse intermediate agricultural processing technologies on a rural community in South Africa. The papers by Rawat, Buys et al. as well as the paper by Niwa & al. point out cultural variables and give specific views of the world competitiveness,

At the end of this section Jacquot & al. argue that a sustainable development policy requires new strategic approaches and an innovative knowledge management within companies. They highlight that taking more environmental criteria (environment, culture, ethic...) to evaluate strategic decisions constitutes an improvement in strategy definition practices.

The third section is more precisely dedicated to innovation, new product and technology development. According to many researchers the way an idea is "processed" into a new activity influences success. As a consequence, applying a sustainable development approach, the management of each step constituting the new product

development process (NPDP) becomes a key factor for technology valuation. Cost, marketing targets and quality criteria are no longer the only target variables to be taken in account to generate value.
Thus researchers still need a better understanding of in situ actual NPDP. Coccia et al. address the gap describing the case of italian companies. Badir et al. focus on Biotechnology start ups and list the obstacles to applying formalized processes in this particular context. The case of incubators is described by Von Zedtwitz et al.

Some of the following papers focus on one particular phase of NPDP considered as an operational process. Vayvay et al. article spans a large range of innovative concepts generation. Valette et al. also study the very first stages of design: before initiating new concepts. They discuss usage as a notion facilitating multi-actor innovation processes management and multi disciplinary integration. Ragus et al. expose the problem of collaborative tasks and detail the limit and advantages of new technologies like virtual environment.

Because innovations deals with uncertainty, technology managers gains useful insights by evaluating their design decisions. Maravelakis et al. suggest new best practices in the field of benchmarking and Chan et al. contribute to quality assessment.
In term of strategy, Ishioka et al. investigate a high tech panel of Japanese firms and highlight several major competitive factors that lead, after analysis, to four types of strategies that companies can develop to improve their NPD. Some of these factors are consistent with the observation of Smith describing cluster creation and development in several Canadian companies. Kim et al. propose an economic model adopting multinomial logic to describe technological push and demand pull.

The last group of papers deals with the global management of NPDP focusing on information transfer and treatment. Boersma et al. present the role of ERP. The case of Brazilian firms is described by Chauvel et al. Abi Raad suggests several rules in order to develop the customerization of the design process and customer relation management as a basic strategy.

We would like to acknowledge the support of various and generous partners in the 2003 Nancy IAMOT Conference:

- Academics: l'Académie des Technologies, l'Ecole Centrale de Lille, l'Université de Technologie de Compiègne, l'ENSAM Paris, le CERAM Sophia-Antipolis, l'ENSGSI Nancy, l'INPL;
- Companies: Groupe Taittinger, Lyonnaise des Eaux, FMA, Creax, CM International;

- Institutions: l'Académie des Technologies, l'INPI, l'ANRT, le Conseil Régional de Lorraine, la Communauté Urbaine du Grand Nancy, l'INIST, European Commission (Brussels).

Our gratitude goes to the authors and participants whose rigor and enthusiasm make this book possible.

INPL-ERPI, Nancy, France, November 2004

Vincent Boly
Laure Morel-Guimaraes
Tarek Khalil

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LIST OF CONTENTS

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His research is based on the set of themes of the "usage" in the design process. The main hypothesis is that the effective user integration in the product design process is only possible when "usage" is a common reference frame in interdisciplinary product design team.

Then this common reference frame based on usage can be the start point for supporting the creativity in the early product design phases.

Research Keywords: Usage, Innovation, Cooperation, knowledge management

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Dr. Yasuda's research articles have appeared in many academic and professional Journals in English and Japanese.

SECTION I

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

1

Understanding the Difference Between Information Management and Knowledge Management

Jose Claudio Terra, Ph.D. and Terezinha Angeloni, Ph.D.

INTRODUCTION

It is commonplace these days to say that knowledge is the most critical asset to be managed. Yet not many people – particularly not practitioners – invest very much time in learning about what knowledge really is and how different knowledge management is from information management. Particularly IM-focused individuals or software vendors tend to treat IM and KM as the same thing. However, the very act of managing and management science itself can be seen, to a large extent, as the application of human knowledge in an organizational context to achieve desired outcomes. Thus, managing knowledge can be defined very narrowly or broadly depending on a person's specific goals or perspective.

A narrow definition of KM is usually associated with the deployment of information management systems, while broad definitions are usually associated with the softer side of management such as leadership style, organizational culture, rewards and recognition programs, etc. In this article, we will argue that despite the growing focus on information management systems as a key enabler of KM, knowledge management as an emerging discipline depends on the fusion of the contributions of many disciplines, including philosophy, psychology, sociology, management and economics that until recently did not cross paths.

DEFINING INFORMATION AND KNOWLEDGE

In order to fully understand the differences between IM and KM, it is important to review basic definitions of information and knowledge. There has been no shortage of authors providing their own definitions of these terms. Thus, in this paper, we will not present our own definitions, but rather discuss the management implications of definitions provided by some leading authors. In general, the definitions of information tend to be far more uniform and less complex than the definitions of knowledge. Information is usually defined as:

- "Organized data" (Saint-Onge, 2002);
- "Data endowed with relevance and purpose" (Drucker, 2001);
- "Interpreted data" (Probst et alii, 2002).

These definitions are similar to many others that point to the fact that information includes human participation in the purposeful organization of raw data.

Defining knowledge, however, is a much more complex task. One way to tackle this task is to go back to the roots of the Greek word episteme, which means absolute truth. That seems broad enough to include many subsequent definitions. What is absolute truth and how to reach it, however, have been questions plaguing many generations of philosophers since Aristotle and Plato. We will not discuss all the perspectives that many great thinkers have offered since then, but highlight that two main views have been put forth about how we learn and acquire knowledge: empiricism and rationalism (Gordon, 2002). The interplay between authors coming from these two camps offer us the current more accepted understanding about knowledge. Namely, knowledge can only reside in one's mind and is the result of human experience and reflection based on a set of beliefs that are at the same time individual and collective.

The same complexity is highlighted by some of the leading authors in the emerging field of knowledge management. For instance, Davenport & Prusak (1998) define knowledge as a mix of fluid experiences, values, contextual information and intuition that provides a structure to evaluate and incorporate new experiences and information. It originates and is applied in the minds of individuals. This is similar to Nonaka & Takeuchi's definition (Nonaka & Takeuchi, 1995): "Knowledge is true and justified belief".

We could highlight many other definitions, but in our opinion, they would not add significantly to further clarifying the difference between information and knowledge. In general, all authors point to the complexity of knowledge compared to information. The key difference can be summarized by the role played by human beings. In the case of knowledge, as simple as it may seem, individuals play a prominent role as creators, carriers, conveyors and users. In contrast, in the case of information, these same functions can happen "outside" humans and without their direct influence.

KEY DIFFENCES BETWEEN INFORMATION and KNOWLEDGE MANAGEMENT

We will analyze the differences between IM and KM according to five different dimensions :

- Interplay Between Information and Knowledge
- IM and KM Projects: different scopes, approaches and measurement systems
- Organizational Learning and KM
- Broad Concepts of KM
- Protecting Intellectual Capital: IM and KM Perspectives

Interplay Between Information and Knowledge

From a management perspective the key difference between information and knowledge is that information is much more easily identified, organized and distributed. Knowledge, on the other hand, cannot really be managed because it resides in one's mind. Thus, KM is essentially limited to creating the right conditions for individuals to learn (using information and experiencing the world) and apply their knowledge to the benefit of the organization. The application of one's knowledge can, hopefully, thereby be translated into relevant information that is shared and used, new products and actions that create value.

This understanding of knowledge and KM can leads one to think about the well-known "spiral of knowledge creation" proposed by Nonaka & Takeuchi (1995). Although the authors agree with Nonaka & Takeuchi's view of how knowledge is created, we find it important to highlight that they do not clearly explain the different between information and knowledge. In our opinion they use the term "explicit knowledge" almost as a synonym for the word "information". This interchange, in our opinion, may have led many practitioners that read their contribution to quickly to think too much in terms of Information Management (IM) instead of Knowledge Management (KM).

One of the subtle aspects of the two distinctive approaches mentioned in the paragraph above is that as knowledge is turned into information (documents, best-practices, databases, etc) a transformation occurs. Information is not the same as knowledge in a different state (outside an individual's head). During the process of speaking and writing individuals are not just "downloading" (using the metaphor of a typical download from the Internet) what they know. They are, in fact, learning and transforming what they know into something that is materialized as symbols and that resembles what they know, but that is inherently different from what they know. As Polany (1997) once said: "We know more than we can tell". When the required knowledge is somewhat more "easily" translated into codified information, we tend not to notice such an important difference (e.g. instructions to operate a coffee machine). However, when the required knowledge is embodied in one's physical skills (e.g. soccer player) and/or is related to complex knowledge that requires significant experience and analysis of many variables (e.g. family doctor), then the inherent difficult of converting knowledge into information becomes more evident.

A very interesting perspective that clearly distinguishes KM from IM has been offered by Von Krogh, Ichijo and Nonaka (2000). These authors built upon Nonaka's initial work and put forward the idea that it is not possible to manage knowledge. According to their view, one can only prepare, and hopefully positively affect the knowledge creation process through many managerial actions and decisions. The key for these authors is not the deployment of sophisticated information technology, but the facilitation of conversations locally and increasingly among people in different locations. Thus, KM is about supporting conversations and supporting a humanistic perspective of work. It is also deeply ingrained in the values of the organization since knowledge in their opinion is also true and justified belief. In our opinion, the perspective offered by these authors highlights another key difference between IM and KM: IM is usually not concerned with the actual process of knowledge-creation or innovation.

KM systems are necessarily much more human-centric than IM systems or initiatives. Thus, KM practitioners must recognize that increasing the richness and quality of the available information sources and the interpretative capacity of employees is far more desirable than simply increasing the quantity of information available. Information per se can be meaningless and irrelevant without proper context. Thus, two of the main concerns of KM (and traditionally not of information management) should be (1) the provision of context for and validation of available information and (2) increasing the connections among people (who have knowledge) that would likely not occur without the help of a KM system. With these goals in mind, context about the main information sources (especially unstructured information) is significantly enriched by including additional details such as (Terra & Gordon, 2002):

- Who created the information;
- What is the background of the authors;
- Where and when was it created;
- How long will the information be relevant, valid and accurate;
- Who validated the information;
- Who else might be interested or has similar knowledge;
- Where was it applied or proved to be useful;
- What other sources of information are closely related;
- How to test some of the concepts (e.g. through templates and simulation).

IM and KM Projects: different scopes, approaches and measurement systems

Terra and Gordon (2002) have suggested that the term "KM project" should never be used as if it pertained to the same category as an IT/IM project. KM projects should take a holistic or organic view of the enterprise and should encompass different initiatives in many areas: certainly in IM, but also in HR, organizational design, internal communications and so forth. KM is more closely associated with the "act of managing" than IM. In this sense, KM is never-ending. It is defined by the identification of people's expertise and the interplay of people with people (tacit knowledge-sharing) and people with information systems (two-way road of knowledge capture, reuse and recreation). Given that they are highly dependent on people's previous knowledge, motivation and willingness to create, act, share and/or codify their own individual knowledge, KM processes are far more complex than IM projects. However, KM is increasingly dependent on the support of a solid IT infrastructure. This dependence is particularly evident in large and geographically dispersed organizations where significant numbers of knowledge-workers need to collaborate with peers who are not in the same location and are constantly creating, applying and storing information for further reuse by people whom they may never meet personally.

It is our opinion that KM projects need to be a lot more value-driven than traditional IT/IM projects. Whereas the success of IT/IM projects is often judged based on technical achievements (besides cost and timeline considerations), the success of KM projects has less to do with technical achievements and more to do with changes in behavior or actions derived from connections or learning opportunities that the projects facilitated. In general, therefore, IM solutions should be considered as distinct from KM projects, but also key enablers of greater levels of collaboration and knowledge-sharing.

Without a clear understanding of how knowledge is created or utilized by human beings, and how certain design solutions impact the knowledge creation process, companies implementing KM initiatives may fall again prey to the same traps that scuttled of the most disastrous IT-laden initiatives of the nineties: the re-engineering fad. These traps included (Hamel, G. & Prahalad, C. K., 1994) :

- Not considering the issues of past organizational learning in the form of the (tacit) knowledge of employees and future organizational learning in terms of the need for the company to be continually learning and adapting itself;
- Developing technology-intensive business process redesign solutions without understanding how knowledge and judgment are related to such business processes and the willingness, or readiness, of organizations to change;
- Impeding lateral links and peer exchanges due to a single-minded focus on achieving longitudinal and cross-functional links and efficiency gains; and
- Failing to consider the practical needs of employees, focusing instead on meeting process requirements. In John Seely Brown's and Paul Duguid's words, the reengineering movement failed to understand that: "It is the practice of the people who work in [an] organization that brings process to life, and, indeed, life to process" (Brown & Duguid, 2000).

Finally, one of the most telling differences between IM and KM projects is related to the measurement of results of such initiatives. IM follows a long tradition of information technology projects that tend to associate results (or Return on Investment, ROI) with very quantitative results and some intangible results (the so-called "nice to have"). In many cases showing positive ROIs in very short timeframes (in studies often "sponsored" by software companies). KM projects, on the other hand, require a very different approach because they rely more heavily on the willingness of individuals to modify their behavior and share, codify and use information and their own personal knowledge to the benefit of the organization.

Organizational Learning and KM

Although KM practice has distanced itself from the organizational learning field, it is possible to argue that from a theoretical point of view, the knowledge management discipline can also be seen as a direct inheritor of the organizational learning field. Chris Argyris (1977), Peter Senge (1990), Edgar Schein (1993) and others have made important contributions to KM in terms of looking at how individuals and an organization can learn continuously through self-knowledge, systemic thinking, openness and dialogue. Further, Keating, Robinson & Clemson (1999, p.8), highlighted the difference between knowledge and learning: Knowledge – encompasses what we know and what we can do – indicates a state and, therefore, potential for action and decision. Learning, on the other hand, refers to any change in a given knowledge state.

Thus, knowledge can be seen as a "stock" and learning as the "flow" of knowledge. This distinction, although apparently trivial, is of utmost importance for the design of KM initiatives. The competitiveness of an organization depends both on its current stock of knowledge and on the flow of individual and organizational knowledge. Whether an organization should put more emphasis on the "stock" or "flow" of knowledge depends, to a large extent to the type of industry, nature of work and value proposition. In markets that are more stable and where work tends to be more repetitive, KM's primary goal should be to effective reuse existing knowledge that has been translated into detailed information. Where the competition is essentially innovation-driven and work tends to be more varied, learning and focus on the flow of knowledge will deliver better results. These two opposing KM models are, of course, just two extreme poles of a continuum. Reality often lies somewhere between these two poles.

Broad Concepts of KM

After reviewing KM schemes from leading KM authors (such as Nonaka & Takeuchi, Karl Wiig, Michael Earl, Edvisson, Snowden, Inkpen & Dinur, Van Buren and Despres & Chauvel) Despres and Chauvel (2000) show that most KM models and perspectives include both a structural and a prescriptive aspect. They suggest that the following themes are recurrent:

- Time: knowledge is not seen as a store, but as a dynamic process that can be better understood in terms of processes occurring in a frame of time;
- Types, Forms, Embodiments: knowledge has many classifications that are usually consequential in nature;

- Social Space: most authors recognize that the individual is the only holder of knowledge, but that knowledge only becomes relevant in a social space or in an action.
- Context: most authors agree that nothing has any meaning outside a context;
- Transformations and Dynamics: this has much to do with the more practical, abundant and prescriptive nature of KM definitions and includes concepts and practices such as: socialization, externalization, combination, internalizations, inventorising, auditing, experiencing, articulation, reflection, codification, dialogue and reflection.
- Carriers and Media: this theme refers to the infrastructure of transformative and dynamics processes and highlights the methods and the "how" of KM;
- Knowledge Culture: many authors also emphasize the learning aspects and impact of different cultures.

The multiple perspectives of KM have also been clearly presented by one of the authors' own thesis (Terra, 1999). He has argued that the management practices that are related to effective KM and, as such, to fostering learning, creativity and innovation, are strongly associated with: leadership and culture focused on experimentation, innovation and the continuous search for big challenges; multidisciplinary teams; the creation of different opportunities for establishing personal contact, thereby developing, diffusing and assimilating the tacit knowledge of employees; ample access by all to information and knowledge; encouragement of diversity; investment in professional and personal development; and, finally, support for the establishment of close individual and organizational links with the external environment and use of multiple performance indicators (in particular those that account for Intellectual Capital, knowledge flows, etc).

A broad KM perspective should also be closely linked with an organization's corporate/business strategy. Only knowledge that supports unique value propositions and core competencies is really worth pursuing and protecting. Unfortunately, various surveys (Zack, 1999) completed in the late nineties with hundreds of companies from the USA and Europe, demonstrated that this link is rarely established in most KM efforts This brings us to suggest that KM necessarily involves two intertwined levels of action: strategic and tactical.

In organizations where KM is well structured, the actions in these two levels should be coherent and aimed at bringing coordination to the tasks of identifying, creating, organizing, sharing, disseminating and using the sources of knowledge available for the organization. The strategic level is a more analytical level of action that should have a top-management perspective. It should be focused on determining what types of knowledge will provide a competitive edge and how the organization will acquire, develop or maintain such knowledge advantages. Once the key decisions and strategies are formulated, companies can engage in tactical actions such as the implementation of organizational processes, HR policies and IT infrastructures that will support the chosen strategic directions (Terra & Gordon, 2002).

Protecting Intellectual Capital: IM and KM Perspectives.

There are also very important differences be tween information and knowledge management when it comes to strategies for protecting of valuable intellectual capital. An IM perspective will lead organizations to put too much emphasis on "front-door security", badges, firewalls, permission and access levels, etc. Although in many cases these measures can be of utmost importance, in many other circumstances, truly important knowledge resides within people's heads and an active and systematic protection strategy of this type knowledge should be put in place. In practical terms, there are only two types of strategies to protect this type of knowledge: retention policies and the circulation of knowledge. Retention policies are more clearly understood. Circulation of knowledge strategy relates to actively developing mentoring (helping juniors learn from more senior people that hold strategic knowledge) and fostering teamwork & communities of practice (making sure a number of people develop knowledge collectively, therefore, reducing the potential of losing knowledge suddenly by the departure of a particular individual).

CONCLUSIONS

Knowledge as an asset or resource, unlike information or data, is not easily understood, classified, shared and measured. It is invisible, intangible and difficult to imitate. Expanding the knowledge base within an organization is not the same as expanding its information base. Nonetheless, there is a great deal of confusion among information management and knowledge management.

If IM and KM are so different in terms of scope, depth and variables involved, why are the terms often misused?

It is our opinion that the software sector should is partially to blame for this confusion. Indeed, the influence of the software industry on the adoption of many new management practices and techniques has not been studied enough. The confusion between IM and KM is, in our opinion, just one of the latest symptoms of a much deeper trend: how the software industry is helping to shape management practice, language and theory.

In the last few years, much of the "buzz" in management practice – reengineering, ERP, CRM, PRM, permission marketing, collaborative commerce, etc – has originated in the software industry in the last few years. The pace of these developments has been frantic and Academia is having a hard time keeping up with and understanding the real implications of each one of these new "waves". Developing a deep understanding of each one of these many "management waves" is certainly very important. However, it seems to us that Academia should put much more effort into understanding the general process of how these "waves" are developed, evolve and become a common fixture of management practice.

In the context of the above discussion, we believe that is valid to ask whether KM is just a "buzz", a new "wave" or indeed a new discipline. In order to answer this, we think that it is highly appropriate to quote Professor Robert M. Grant from Georgetown University. According to Grant (Grant, 2000, p. 39): "What Knowledge Management offers us is insight into aspects of management that we have failed to understand properly because of our failure to consider the nature and characteristics of knowledge". We believe that although KM is not necessarily a totally new discipline, it is having a very positive impact on management theory and also on information management. Most importantly, KM represents a shift from a focus on information to a focus on the individuals that create and own knowledge.

Finally, we must highlight that supporting the knowledge creation and dissemination process is certainly not a new concept. This has been a major concern for management theory and humankind in general for a very long time. However, after spending much of this article comparing IM and KM, it is important to remember that KM practice has been deeply influenced by recent improvement in our ability to process information and to communicate through many new devices and technologies in synchronous and asynchronous modes. The challenge, then, is to develop a coherent, aligned, comprehensive, systemic and systematic approach to KM that takes into consideration the constant interplay among organization strategy, values, human capital and information technology infrastructure.

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Management of Technology: Key Success Factors
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2

FIRMS' WIRELESS APPLICATION NEEDS ASSESSMENT IN TECHNOLOGY SELECTION

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INTRODUCTION

A Mobile Internet market is forming in Europe (Edelmann et al. 2002; Kankare 2002). A huge number of new terminal types and many operating systems are entering the market (Kytölä & Sissonen 2002). Access network technologies like GPRS, UMTS and Wireless-LAN (802.11x) are competing each other.

Capabilities to react to changing environmental conditions define the success of a firm (Hamel & C.K.Prahalad 1994; Schumpeter 1942; Teece, Pisano, & Shuen 2002). Technology evolves through periods of incremental change and technological breakthroughs (Tushman & Anderson 1986). The Mobile Internet and Wireless Technologies open a completely new environment for firms to re-create or re-innovate their business concepts and improve their operational efficiency (Laaksonen & Edelmann 2002). The innovation of new business concepts based on technological opportunities is a new way of improving the competitiveness of a firm. This does not require the firm to create new markets; it just has to invent a more efficient way of approaching the market (Hamel 2000; Schumpeter 1942).

In this paper Wireless E-Business is defined as an Internet initiative, *consisting of a wireless component,* that transforms business relationships, whether those relationships be business-to-consumer, business-to-business, intra-business, or even consumer-to-consumer (adapted and modified from Hartman, Sifonis, & with Kador 2000).

Finnish firms are starting to build new applications based on the Wireless E-Business. Correct technology selection is crucial for the best return on investment as well as the manageability of the systems and user support. If the firm manages to choose its own infrastructure so that it satisfies most of the needs of the firm's applications, the return on the investment will be the best. On the other hand, technology selection contains a risk if the firm
chooses a technology path, which dies out and the switching costs to new technologies are high (Tuominen & Kivijärvi 1999).

Companies planning to integrate wireless devices into their current infrastructure should take the following three steps: 1) conduct an inventory of current technology to determine what exists and how much is being spent, 2) constantly raise the question of how wireless technology can be used to modify current and short term plans, and finally, 3) ensure that the current or planned architecture includes wireless technology (Barbero 2002).

By using lead users (von Hippel 1988) and the process developed (Laaksonen et al. 2001) for the Group Decision Support Systems (GDSS) laboratory based on earlier case studies and similar types of developed, we assisted lead user groups to create a large amount of beneficial, future Wireless E-Business applications and new business concepts for themselves.

In this paper we present the results of our study on wireless technology selection based on the needs of the generated applications.

CUSTOMER INVOLVEMENT AND LEAD USERS

Having the customer closely involved during new product development can greatly increase the success rate of new products (e.g. von Hippel 1986; Cooper 1996; Ottum & Moore 1997). Still, many companies do not effectively bring the customer into their new product development process (Adams, Day, & Dougherty 1998; Cooper, 1996).

Von Hippel (1986) notes that users are strongly steeped in their present experience. Hamel and Prahalad (1994) suggest that "Customers are notoriously lacking in foresight". Conventional users or customers are not likely to be able to articulate needs for new types of products, or to be able to easily evaluate the significance of new product concepts or technologies.

Lead users expect to benefit significantly by finding a solution to their needs. They are not the same as "early adopters" i.e. people who purchase an existing product or service – lead users have needs for products or services that do not exist yet (see Figure 1).

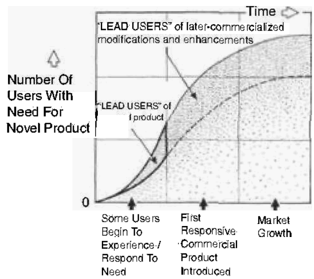

Figure 1. Positioning of lead users relative to the market life cycle (von Hippel 1988)

DECISION MAKING UNDER RISK AND UNCERTAINTY

The concept of risk can be divided into certainty, risk and uncertainty (Knight 1985). Uncertainty can be further divided into parametric and structural uncertainty. Markowitz (1959) and von Neumann and Morgenstern (1947) have presented theoretical approaches to choose between investment alternatives (Kivijärvi & Tuominen 1998).

According to Turban and Aronson (2001) "in decision making under uncertainty, the decision maker considers situations in which several outcomes are possible for each course of action. In contrast to the risk situation, in this case the decision maker does not know, or cannot estimate, the probability of occurrence of the possible outcomes. Decision-making under uncertainty is more difficult because of insufficient information. Modeling of such situations involves assessment of the decision maker's attitude toward risk."

In this paper we focus on improving the methods and estimating real application requirements to reduce risk in management decision-making in wireless technology selection.

TECHNOLOGY SELECTION BASED ON CUSTOMER AND APPLICATION NEEDS

Steele (1989:8) defines technologies as 'knowledge of how to do things' or 'capabilities that an enterprise needs in order to provide its customers with the goods and services it proposes to offer, both now and in the future'. Respectively, from the point of view of a firm's applications, technologies should satisfy application specific needs.

Technology selection can be defined as a management process of making choices between a numbers of distinct technology alternatives and maintaining an appropriate technological infrastructure (technologies, technological capabilities and resources) for a firm. Technology is used to satisfy the needs of firm's applications, and through applications the needs of customers. Technology selection under distinct technology alternatives and distinct applications is illustrated in Figure 2.

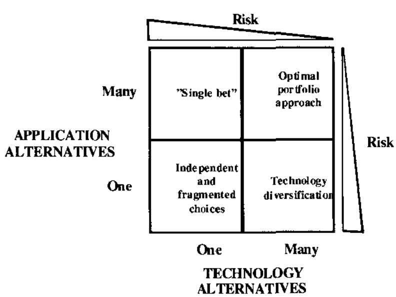

Figure 2. Alternative application/technology choices

Independent and fragmented choices

Applications are considered against technologies one by one. This leads to sub-optimal use of resources, and may result in a too wide technology pool, with too many needed technological capabilities.

"Single bet"

A firm commits to one technology only; all applications are carried out with that technology. This approach contains high risk, if a wrong technology path is selected. Switching costs to new technologies high.

Optimal portfolio approach

Optimal portfolio approach enables portfolio management of applications and technologies simultaneously with lowered risk. A firm needs to maintain a rich portfolio of potential application ideas together with a valid set of technology alternatives. The optimal portfolio approach is applied in this paper.

Technology diversification

In the technology diversification approach alternative technologies are defined for each of the applications. It is possible to cover a broader set of application specific needs, e.g. different access possibilities to a service offering. This approach provides enhanced flexibility in technology, but does not adequately take into account the portfolio view on applications.

Very few studies have explicitly combined customer needs and firm's applications needs in technology selection.

RESEARCH METHODOLOGY

General

In the research and innovation sessions, we concentrated on firms' business application needs. Generic (calendar, address book, etc.) applications were not in focus, because they are already inbuilt features in devices and available as standard type services in the Internet.

In order to evaluate the future business-application needs of a firm, we applied and modified the methods created earlier for the GDSS laboratory (Piippo, Torkkeli, & Tuominen 1999) and combined them with the application of Quality Function Deployment (QFD) method. The acquisition of innovations has been discussed in our earlier papers (Laaksonen, Edelmann, & Suikki 2001) as have technology limitations (e.g. Kytölä & Sissonen 2002).

QFD – Quality Function Deployment

Quality Function Deployment (QFD) has been widely used in product development (Akao 1990, Bossert 1991, Daetz, Barnard, & Norman 1995, Day 1993, Dodd 1997) but it has not been applied largely in technology. The general approach, called House of Quality, contains five tables, Customer needs and benefits, Planning matrix, Technical matrix, Technical response and Technical correlations (Cohen 1995).
In this paper we apply QFD for the wireless technology selection of a firm. In our study customer needs and benefits, as well as the planning matrix were created in the GDSS sessions. The Application requirement matrix in our study corresponds to the Technical matrix, and the technology Selection matrix to the Technical response matrix. We used the following steps to define the best technology configuration for a multitude of the application requirements:

a. Identify customers' future application needs.
b. Define application requirements.
c. Identify present and future technologies available (terminals, access).
d. Define technology capabilities and restrictions.
e. Fill in application requirements – technology matrix.
f. Summarize technologies servicing best application requirements.

(Adapted and modified from Kyeongtaek, Kwangman, & Seungwoo 1996).

Application requirements matrix

For each of the innovations we defined application requirements consisting of

i. user's terminal requirements (capabilities like weight, size, screen, input method, etc.),
ii. application requirements defined by data processing and transfer during the use (capabilities like processor speed, memory, access network transfer speed, etc.),
iii. security requirements (user and data transfer),
iv. support requirements (user, application and technology support), and
v. availability and coverage of the services (terminal, access networks and security).

The application requirement variables and allowed values were defined first. The requirement variables were evaluated for all of the ideas.

Technology selection matrix

The application requirement matrix was then applied to each technology. Each technology was given values 0, 1, 3 or 9 representing the fit of the technology to the requirements for each of the ideas. The values represented explanations: 0 no fit at all, 1 slight or very limited fit, 3 moderate fit and 9 strong fit (adapted and modified from Cohen1995). The matrix method is explained in a simplified model in Table 1.

Table 1. Principles of the technology selection.

Innovations	**Requirements**					**Technology Solution**	
Idea	User & usage	Application	Security	Support	Availability and coverage	Terminal	Access network
Idea 1						Terminal (x)	Network (i)
Idea 2						Terminal (y)	Network (j)
.....						....	
Idea n						Terminal (z)	Network (k)
						=sum(1..n)	=sum(1..n)

Terminals

The terminals were categorized into PC, Laptop, Tablet PC, Web pads, Handhelds, Palmtops, Smart phones, Mobile phones, Pagers and RF-ID devices as shown in Table 2 below.

Table 2. Terminal technologies.

Terminal type	Advantages	Limitations
PC	Full technical capability, expandability	Not portable
Laptops	Portable, functionality, expandability	Size and weight
Tablet PCs	Improved pen writing entry method, character recognition, different screen positioning alternatives	Size and weight
Web pads	PDAs with a big touch screen, no physical keyboard, various operating systems possible	Processing and communication capabilities.
Handhelds	PC like small computers with a color screen and a physical keyboard, touch screen or stylus as pointing device, WLAN or GPRS connection available, PC connection available	Screen and keyboard squeezed due to the smaller physical measures of the devices. Slower processor and less memory.
Palmtops	Smaller than handhelds	Screen and keyboard squeezed due to smaller physical measures of the devices. Often do not have a keyboard. Slower processor and less memory.
Smart phones	Mobile phones integrated with PDA devices	Screen & keyboard size. Slower processor and less memory.
Mobile phones	Small size	Mainly used for calling and SMS.
Pagers	Not used in Europe	
RF-ID	Small size (e.g. adhesive label), low price	Regulatory limitations in Europe (radio frequencies?)

PCs have full technical capabilities and extendibility, but they are not portable. Laptops are portable, i.e. mobile PCs. Laptops have the best functionality and extendibility, but they are restricted by their size and weight from the user requirements' point of view. Tablet PCs are similar to Laptops; they have improved pen writing entry method and character recognition. Web pads are defined as PDAs with a big touch screen without a physical keyboard. They use operating systems developed for mobile devices, such as MS Windows for Handheld PCs, MS Windows CE, Mobile Linux or Symbian (EPOC). A good example of a web pad is Siemens SL4 (Kytölä & Sissonen 2002).

Handheld PC's are defined as PDAs with a keyboard as the primary input device and they are most suitably operated with both hands on the input device. Handhelds have basic connections, such as PC-card (PCMCIA) or CF-card (Compact Flash) slots for network adapters, providing access to network connections. HP Jornada 700 series is a good example of a basic handheld (Kytölä & Sissonen2002).

Palmtops are smaller than handhelds. Their screens are vertically positioned even though they can often be converted programmatically. They have a touch screen input and the display is almost the size of the whole device, typically some hundreds of pixels in height and width. The entry method is normally touch-screen, stylus and character recognition. The operating system is usually Microsoft Pocket PC. Wireless access on palmtop PDAs is typically available through extension jackets. Good examples of palmtop PDAs are Palm's various PDAs and the first Pocket PC-based palmtop PDA, Compaq iPaq (Kytölä & Sissonen2002).

Smartphones are mobile phones integrated with PDA devices. They have a small keyboard, a color screen and inbuilt radio access. They offer at least the basic PIM tools such as memos, contacts/address book, calendar, email, web browser, spreadsheets, and maybe other small office features such as presentation and database tools. They also have full mobile phone features integrated to the device, and so have at least the mobile networks available for data transfer. Usually they include GSM-GPRS capability. Nokia's 9000 series communicators, Handspring (Treo series) and Siemens SX45 are good examples of the category (Kytölä & Sissonen2002).

Mobile phones are mainly phones, but include today PIM functionality and data communication capabilities. They are small, and therefore the functionality is restricted by size.

Radio Frequency (RF) technology is an emerging technology still facing limitations from regulators in Europe. Due to its size and price RF-ID can be considered an interesting terminal technology. Pagers are not used in Europe anymore.

Access networks

From firms' business-application point of view the access network has to supply access to the environment where the user has the need to access the application. It also has to satisfy the communications needs of the application so that user is willing to use the application in his/her normal daily work. The alternative access networks are: GSM, GPRS, UMTS, Bluetooth, W-LAN, satellite networks and ADSL/Fixed network. The access speeds range from 100b/s to 22 MB/s. The availability of the access networks varies a lot: satellite networks cover the whole globe, except indoors, Bluetooth covering a range of 50 meters maximum. UMTS is not available yet in large areas.

RESULTS

Application Requirements

The Application Requirement Matrix is a cross tabulation of all the ideas and application requirements (i-v). The matrix was formed of 970 cells (10 variables, 97 ideas) of which nine ideas, 9.3% of the results, were not suitable i.e. were non-definable for the analysis.

Most of the applications (84.3%) would be used inside and outside the firms' premises. A majority of the applications (71.6%) would be used in dry and warm office type environment. Applications in which a device communicates with the application, represent 30.7% of the ideas. Another large group is Web-type user-interfaced applications requiring either one or multiple page input-output interaction (51.1%). The data transfer requirements of the applications are similarly split by simple small amount transactions, like SMS, representing 29.5% of the applications. Larger data transfer requirements are generated mainly by the Web-interface-type applications (51.2%).

96.6% of the applications require at least regional coverage (larger than a building) to be a feasible investment.

The requirement for offline or online video demand (1MB-100MB) represents only 6.8% of the applications. 70.5% of the applications require real mobility and 76.1% require ubiquity. On the other hand, 75.9% percent of the feasible scope for investment of the applications are estimated to be within a country or less. For security, 68.2% of the application requirements are satisfied with medium high security or less. Half of the applications require deep application of the application for application support. Especially high portion (86.4%) of the applications require firm IP, Internet and Mobile Network knowledge for network support.

TECHNOLOGIES SATISFYING FIRMS' NEEDS

For the application requirements we have defined the Technology Selection Matrix consisting of ten terminals and six access networks. We have also defined the primary (best) and secondary (second best) technology for each application. The Technology Selection Matrix consists of 1940 cells (97 ideas x 16 technologies and four columns for primary and secondary choices).

Terminal selection

Comparing first each technology against the application requirements, we find out that a PC is not a viable terminal choice in practice. 88.4% of the requirements do not fit with the capabilities of PCs. Laptop (16.4%) and TabletPC (24.4.%) can solve approximately one fifth of the applications well (strong fit). Both handhelds (43.0%) and palmtops (44.2%) can satisfy almost half of the needs. Smartphone can alone satisfy 61.6% of the application requirements. A very interesting and commonly overlooked technology, RF-ID, can solve 16.3% of the requirements. The best terminal for the application requirements is displayed in Table 3.

Table 2. Primary terminal satisfying application requirements

Primary Terminal

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Laptop or TabletPC	15	15.5	17.4	17.4
	Webpad	4	4.1	4.7	22.1
	Handheld or Palmtop	24	24.7	27.9	50.0
	Smartphone	27	27.8	31.4	81.4
	Mobile Phone	2	2.1	2.3	83.7
	RF-ID	14	14.4	16.3	100.0
	Total	86	88.7	100.0	
Missing	System	11	11.3		
Total		97	100.0		

Smartphones serve best the application requirements by 31.4%. Handhelds and palmtops were considered so similar that the groups were combined. They solve best 27.9% of the application needs. Similarly, Laptops and TabletPC were combined and they serve 17.4% of the application needs. RF-ID was especially well presented in identification and logistics management applications, representing satisfactory solution for 16.3% of the applications.

As an interesting outcome in results we can point out machine access technologies. There are not really well suited technologies in our study for machine communication. In many cases machines do have their own automation, but wireless communication technologies suit the application needs only adequately. Some of the applications would require simple terminal device containing sensors, microprocessor and radio access.

Access network selection

Comparing each access technology against the application requirements, we can say that both GPRS (56.0%) and UMTS (63.1%) satisfy well approximately 60% of the application needs. Compared to Wireless LAN (802.11x) (4.8%) the difference is remarkable. As a short-range radio access RF-ID seems to be slightly better (20.2%) than Bluetooth (17.9%). Due to the limitations for indoor use satellite networks did not have a role as an access network.

If we then look at the primary access network selection we can see that GPRS is by far the best choice, satisfying 56.0% of the application requirements. The primary access network selection is presented in Table 4.

Table 3. Primary access solution for application requirements

Primary access

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	GSM	2	2.1	2.4	2.4
	GPRS	47	48.5	56.0	58.3
	UMTS	9	9.3	10.7	69.0
	W-LAN	4	4.1	4.8	73.8
	Bluetooth	6	6.2	7.1	81.0
	RF-ID	15	15.5	17.9	98.8
	ADSL / Fixed	1	1.0	1.2	100.0
	Total	84	86.6	100.0	
Missing	System	13	13.4		
Total		97	100.0		

GPRS combined together with GSM and UMTS these access technologies solve 69% of all the application requirements. This can be explained even by one strong requirement, which is the ubiquity. In order to achieve availability everywhere in Europe, 67.1% of the applications require GSM/GPRS level access availability. W-LAN can be considered as a solution only in 4.8% of the application requirements.

DISCUSSION AND CONCLUSIONS

Firms are about to start investing in platforms on which they can build their future Wireless E-Business applications. It would be very naïve to suggest that only one technology satisfies all the needs of the users and applications. In order to manage also the costs, risks and uncertainty, managers choose standardized bundles, which help them to do both. On the bases of the presented results we suggest that companies could set a standard for Smartphone and Tablet PC for terminals and GPRS and W-LAN for the access network. This would solve most of the mobile staff's application requirements from technology. On the other hand, machine automation requires more attention, because the technologies available do not yet satisfy the application needs well.

24-7 support will be an important feature for the applications in the future. Users will be moving around continents and across borders, and especially network support will become crucial for the users. This is good news for mobile operators.

Taking into account that Wireless E-Business applications are rare, there exists a big efficiency improvement potential. Taking also into account the fact that the planning, testing and implementing of a large business application takes from two to four years, and simultaneously the fact that Moore's law works for the performance and price of the technology, firms should already now be prototyping and piloting applications.

Security is not really a problem. The security requirements of an application, estimated by the value of the information, seemed to be generally quite low, so they can be solved satisfactorily already now.

Reliability of the results

The application of the lead-user approach makes it possible to see into the future concerning the needs that will be generic in the marketplace. This information is quite useful in technology selection, and it has been found particularly useful in rapidly changing industries like the ICT industry. The QFD-based approach utilized in this study also enables a thoroughly customer-oriented and transparent technology selection: customers' needs can be clearly integrated in the selection and evaluation of technologies, and it can clearly be seen by the approach which customer needs and requirements can be affected by various available technologies and in which manner they can be affected. Such approaches should be particularly useful in fast-developing technology-based industries like the ones in this study. The risk involved in the selection can be reduced. In addition, it may be possible to change not only the selection approaches with lead-users and QFD–types of tools, but even the whole firm culture towards a more customer-oriented one. This is significant, because in technology-based companies the technology-orientation is often built-in in the firm culture for instance due to the technological background of the personnel (see e.g. Webster, 1991).

Reliability of the process

At least three elements affect the reliability of the process itself in relation to the results: the time for brainstorming, learning and the environment itself. The time for brainstorming was set on the average to 30 minutes to limit the number of ideas into around 50 in order to manage the process in the planned time. This may have limited the idea generation. However, this problem was eliminated by the tools – new ideas generated at later stages of the process were added in the idea portfolio thanks to the flexibility of the software used. This also happened during all of the sessions held.

Repetition with new groups would probably have created some new ideas. The environment was kept the same over the sessions. All the sessions followed the same process with the same chairman. The timetable was kept easily in all the sessions. The feedback of the process from all the participating groups was good. Therefore we can assume that the reliability of the process was good.

Validity of the ideas

The validity of the generated ideas depends on the representation of the lead user group and the reality of the ideas generated. The participants of the first session were from the two largest product groups of a firm, from the corporate IT and Maintenance Department of one paper mill of the firm. Similarly, the other group represented different parts of the firm. The members of the session were highly committed to the process.

However, does one group of lead users represent all the firm's lead users if it has more than 40 000 employees altogether in tens of countries around the world? When thinking of the validity and the value of the ideas generated we have to accept the fact that the achieved ideas represent only a small number of the potential ideas that could have been generated by the total personnel. On the other hand the ideas generated in the session were themselves valid and valuable for the firm.

Application requirements and technology selection.

One person did the application requirement definition and technology selection for the applications. This can be considered as a weak point in the application of the method. However, it also brings in clear stability into the estimates. In this case the person had more than ten years of practical experience in paper industry applications and ICT technologies.

NOVELTY OF THE STUDY

The novelty of this study is partly based on the novelty in the combination of various data gathering and analysis approaches, as well as the application areas.

Several of the paired combinations of these are rather unique already in themselves in the found literature. The combination of the various issues altogether is even less likely to be found elsewhere in literature. Some of the most important combinations are:

i. The use of QFD-based customer-oriented approach in technology selection
ii. The lead users approach supported by GDSS, resulting for instance in useful added information about the lead users' needs and information useful in technology selection as well as the efficient use the of lead users' limited time, allowing to gather much information in the given time
iii. The lead user approach and lead users used in technology selection, potentially extending the time-horizon and resulting in reduction of risks in the selection
iv. Need –based approach in technology selection, particularly in ICT business–related wireless technology selection for forest industry wireless applications.

GENERALIZABILITY OF THE PROCESS

It is difficult to show how the results can be generalized and how the approach can be applied to a larger group of companies, on the basis of the described cases only. However, since we have found the approach both quite useful in the technology selection, as well as easy to use and quite transparent and simple to understand, it seems that there is a clear potential for a wider firm use, particularly in similar types of technology selection situations and fast-changing hi-technology industries, to reduce risk decision-making. Although we have so far tested the approach on two paper industry firms, we find no reason to suggest restricting the use of the approach only in paper industry. We believe that the approach would be useful also in other industries due to the found general advantages.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

3

PROPOSAL OF AN APPROACH TO PRESERVE THE DECISIONS AND ALTERNATIVE SOLUTIONS ON THE DESIGN PROCESS

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INTRODUCTION

The current economic context requires companies to innovate, to be permanently in technological and market monitoring, to be pro-active and to capitalize their know-how (Griffin. 1997, Karlsson. 1997)

In this paper, we distinguish creative design (based on pure invention, our capability of imagination), innovative design (the way of new technological solutions starting from technologies existing on the market) and routine design (when the designers are limited to reach compromise choices about the dimensioning of components) (Vissers. 2001).

Our research takes into account the context of innovative design. Traditionally, to carry out a technological project, designers explore few solutions, because they lack time and means. The lack of time is due to the short time to market (Norton. 1992).

Companies have to put their product on the market more and more quickly. The market or rival companies force them to reduce the design time limit. This phenomenon leads the designers to adopt compromise solutions quickly. Thus, they reject some solutions which could prove innovating.
These phenomena of "time to market" and "compromise choices" sometimes lead the designers to adopt technological solutions without objective justification criteria (Karlsson. 1999).
Unfortunately, when this solution does not fit into the next project stages, it is very hard to determine the decision which led to this choice.

Our objective is to build a design process which allows the memorization of decisions and especially the preservation of the range of all possible solutions, including the solutions not studied.

These alternative solutions would be able to lead to new innovative products. Thus the preservation of the range of solutions contributes to increasing the knowledge capital of the company and consequently its innovative potential.

In the same way, it is essential to preserve the criteria which allow the designers to make the choice between several solutions. The customers or people in charge of the product requirement definition could be persuaded to change some constraints about the characteristic of the product. And finally the decision criteria could be modified, wich would make it possible to revaluate the solutions not studied.

PROPOSED APPROACH

In order to study the decision process, several existing methods have been studied: Value Analysis (VA) (Miles. 1961), QFD (Cohen. 1995), Axiomatic Design (AD)(Suh. 1995), the Pahl & Beitz approach (PB) (Pahl and Beitz. 1996), Concurrent Engineering (CE) (Sohlenius. 1992), Robust Design (RD) (Taguchi. 1993), Design for Manufacturing (DFM) (Boothroyd. 1994) and the TRIZ method (Altshuller.1988).

Therefore we adopted an abstract dimension for the methods studied, the various representations of the development process provide us with a common vision called “4C vision”, based on 4 essential phases: data collection and analysis (Collect); creation (Create); construction (Construct); and growth (produCe) (Cavalucci *et al.* 2000).

After analyzing the various design methods, we have noticed that these processes don’t take into account the decision phases. These models only show which actions have to be executed in the process. However in the new product design project, the decisions require an important place. Unfortunately these models don't have at their disposal tools which could integrate in the design process the decision stage or the justification for choosing solutions.

Our aim here is not to understand and to describe in an exhaustive way the several cognitive processes which run when the designers have to take a decision.
We will only try to make a realistic representation of the way decisions could be integrated in the product design project. The idea of our proposal is to build a system of "project memory" in which the designers could preserve the decisions with the possibility of establishing criteria of identification:

- about the decisions (authors, date, origins and consequences, causes and justifications),
- about the solutions (characteristics, selection criteria, origins and consequences).

The final aim is to:

- guarantee the cohesion between collected information, decisions taken and actions performed;
- simulate at each stage the decision repercussions on the processes;
- preserve the various decision-making ways (origins and consequences) whether they are successful or not.

First of all, the main structuring concepts and their links were identified. These concepts and links are presented in fig. 1 by means of a UML class diagram (Each italic word in the following text corresponds to a class on the class diagram).

The *Project* is specified (composed) by a set of *Functions*. Each *Function* may be broken down into several sub-functions according to a breakdown decision (*BreakdownDec*). Each function may be also defined by many *Criteria*. Two kinds of Criterion have been highlighted: *Measurable Criterion* and *Subjective Criterion*. The measurable criteria are used to evaluate *Technical Solutions* and the *Evaluation* class is used to store the evaluation result.

The *Decision* class aims to store information about particular decisions. Two main properties are presented here: the date of the decision and its justification.

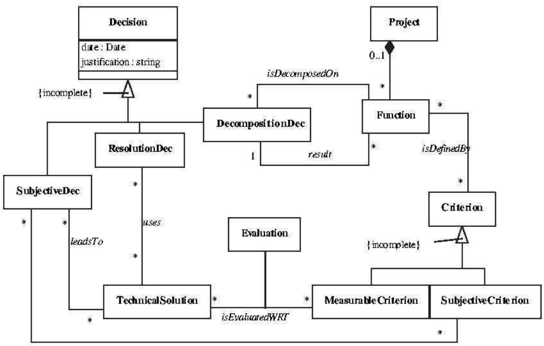

Figure1. UML class diagram

Three kinds of users of this system were identified:

- People in charge of defining products requirements are called "Technical Architects". Their roles are to specify the required functions and define the acceptance criteria values of the final solution. They can be customers too;
- The "Designers" explore concurrent technological solutions; they make the design choices;
- The "Experts" increase the knowledge on the system by storing, for example, new technological solutions. They also define each solution criterion.

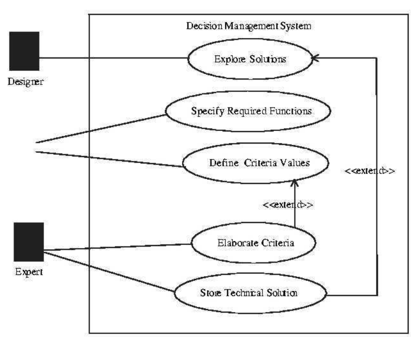

Figure 2: use cases and actors

INDUSTRIAL APPLICATION

The experiment was carried out in a mechanical company. This company is specialised in the manufacture of thermal exchangers. For several years it has developed a range of thermal exchangers, using an unique process based on the rolling up of the exchanger's plate on themselves: the spiral exchangers. This new technique gives them good thermal conductibility. This company wanted to develop several ranges of air-conditioning terminals by using these spiral exchangers. Our project was to design and to manufacture a new model of air conditioning which integrated these spiral exchangers.

The design stage is strongly inspired by the methods proposed. This is a process of transformation of information stage by stage.

The design process model that we adopted for this project was inspired by the traditional models. Each stage is separated by a milestone which constitutes a validation of work carried out, the milestone makes it possible to respect the objectives within the allowed time. This stage is also called "phase of decision". At the end of each stage, the design group has to make a decision. These decisions have to be stored somewhere.

This figure shows the principal steps of this process:

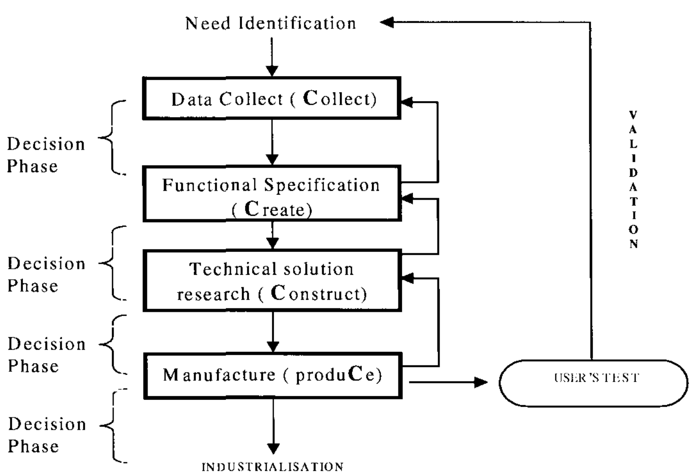

Figure 3: The design process

The first action is to define the need (i.e. the definition of the problem for the product or service design) expressed or not. We have to check that the problem is well defined and adapted to the context. The objective of this step is to clarify the true problem. It is justified by the difficulty of apprehending a correct level for the need specification. In this same stage we also have to identify all actors involved in this project, and their level of involvement. Their contribution is essential for the establishment of criteria.

The second stage is that of data collection and analysis. The aim is to identify all data we had to use. It was also the stage of technological monitoring with the objective to understand how a air-conditioning system works.

In the functional analysis stage, we have applied the previous rules of product breakdown with the aim of defining the functions (see figure 4). The functional specification phases also define the basics characteristics of a product, ranging from cost to environmental impact.

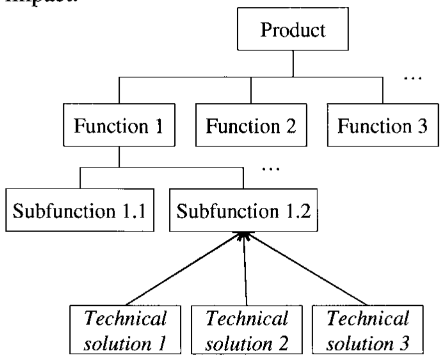

Figure 4 result of technological monitoring: a breakdown of an air-conditioning system

The following list is an extract of criteria the team design has selected:

objectives criteria	**Characteristic of a criterion**
a quiet system	weak vibration, level of noise, under 50 dB
thermal comfort	Weak variation in temperature between fanned air and ambient air of the room: • Variation of T° must be under 4°C • Speed of the air blast < 2 m s-1 • Rate of purity of the fanned air: • Particle size < 5 10-9 m • Particle rate < 250 ppm • Humidity of the fanned air: • Rate of hygrometry must be 80%
Level of ventilation (technical characteristic)	To absorb the primary air – rate of absorption To mix the primary air with the ambient air To conduct the air (the level of the air flow)
A chip system	The price must be under 100 €

subjective criteria	**Characteristic of a criterion**
System must be easy to assemble	Number of people may be under 2
The system must be able to be integrated into several types of environment	A station, a shopping centre, a restaurant, a library
The coating of the system	Quality of the materials, steel, copper, plastic, aluminium, wood

The fourth stage is that of seeking technical solution. Its aim is to provide some technical answers to the needs. Each solution is then evaluated with regard to the criteria and constraints specified in the previous step.

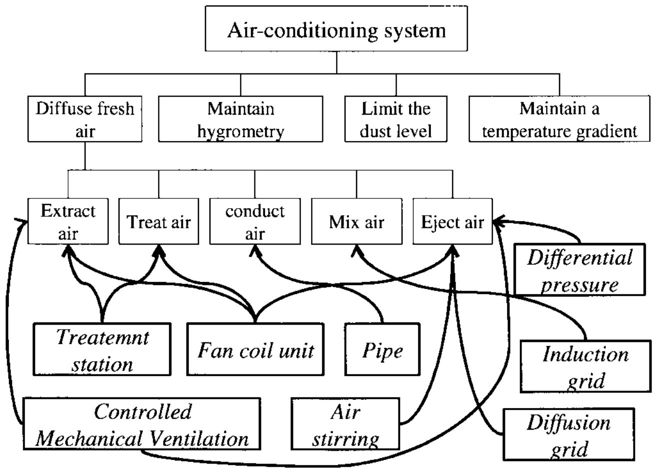

Figure 5: Table of solutions

The preceding figure (figure 5) shows a non-exhaustive set of potential and feasible solutions and their relations with functions. As can be noticed, one solution (Bold box with italic font) can satisfy several functions and one function can be satisfied by several solutions. More particularly, this means that all the solutions are not equivalent: one solution can provide more functionalities than another. This can be used as choice criteria. The designer must then find a combination of compatible solutions in order to fulfil all the leaves of the functional tree.

If the designer cannot find compatible solutions, then some criteria values must be relaxed with the agreement of the technical architect.

Our aim was to choose among several technological solutions of air conditioning system, the one in which the spiral exchanger could have been integrated. In this table of solutions we collected all the solutions in agreement with the defined function and criteria.

This practice allowed maintaining the non studied solutions too. These solutions may be studied for future projects.

CONCLUSION

In this paper we have shown that the company and more particularly the SME had more difficulties to anticipate the trend of technology (and the customer's wish). Our answer aimed to give them "minimal methodological tools" with which they could capitalize all the solutions, not only the right one. Thus they could preserve the solutions not explored due to lack of time, but also the failed solutions.

Our proposal is based on the Unified Modelling Language. The proposed models are the basis of an information system for decision capitalization and management. Such a system allows enhancing, within a short delay, the consequence concerning selection or not of a solution when the designers are led to modify a criterion, e.g.: they can decrease one technological performance criterion of the product (such as the rate of dust filtration for an air conditioning system) with the aim of selling it at a lower price

The industrial application has shown how it could be used in a product design project.

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SECTION II

SUSTAINABLE MANAGEMENT OF KNOWLEDGE AND COMPETENCIES

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

4

EMERGENCE OF BANGALORE AS A GLOBAL TECHNOLOGY HUB: HIGH TECHNOLOGY CLUSTERING IN THE CONTEXT OF CULTURE, TECHNOLOGY CYCLES & KNOWLEDGE STRUCTURES

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INTRODUCTION

With rapid diffusion of Information Technology across all industrial and service sectors, and recognition of its potential as a significant factor affecting economic growth in developing countries began to attract the attention of global community as early as the 1980s. (Kopetz, 1984; Schware, 1987, 1989, 1992, World Bank, 1992). These studies demonstrated that the developing countries, which fail to introduce new information technologies, would be left with an increasingly inefficient system of administration and obsolete production methods. Within the overall set of technologies that make up IT, software is vital since other technologies cannot function without it. It is also the component of growing overall value within information technologies and has 'increasingly become a pervasive technology embodied in a vast and highly diversified range of products and services. It is being asserted that software production is nowadays an industry, essential for the growth of the economies of the developing countries; and promotion of indigenous software industries is, therefore, a priority task. "Computer software has become the 'lifeblood' of business, industry and government" declared a World Bank study in 1993.

Most of the developmental agencies began to recommend that the development of a local software industry could lead to many positive externalities. It is, therefore, necessary for developing countries to be able to adapt software technology. Software production is also seen as the best entry point for developing countries into the IT production complex. (UNIDO, 1983, 1993) because, compared to hardware, software production has much lower entry barriers. Software production is also attractive on account of its specific features because the technology is unusual and functionally complex yet also intangible; modifiable after initial production tools and the final product. (Narasimhan, 1984; Kopetz, 1984, Schware, 1987, 1992). The production process is also highly skill-intensive, while certain types of production rely on labor mobility and on a rapidly growing world market.

India has one of the longest established and largest software industries among the developing countries. Measured in global terms Indian software industry is still in its infancy. Yet it has caught the attention of the global community on various counts. Firstly, rapid pace at which it has grown and integrated with the global economy. According to NASSCOM the industry has registered CAGR of 50% since 1992. Even this year when the global economy has been hit by recessionary trends the software industry has registered a growth rate of 30%. Secondly, and more importantly, how India, from its relatively backward techno-economic conditions has been able to carve out a niche in the cutting edge technology of modern enterprises. Thirdly, the industry has become more easily noticeable due to its heavy export orientation. Fourthly, India is rapidly emerging as the preferred destination for increasing number of fortune 500 companies to outsource their software requirements. "Indian Software engineers have carved out a name in the world market for providing an unbeatable combination of quality software at a low cost". (Chakraborty and Duua 2002). Because of these achievements Indian experience is being posited as a case for 'providing valuable lessons for other countries'. (Heeks, 1996, UNDP 2001; Jackson and Karki 2000). Almost all the writers on India's software industry have attributed this success to the public policy regime created by the government (Heeks 1996; Bajpai and Shastri 1998; Parthasarathy 1999; Arora, etal 2001). The public policy as an instrument of promoting economic development has always been an attractive proposition with the governments of developing economies. However, their efficacy and effectiveness has always been debatable and dependent upon various factors that form the core of regional innovation system. A closer scrutiny of India's software industry and its evolutionary process reveals that the regional factors seem to have played more decisive role. Firstly, the software geography presents a highly uneven picture of India. Bangalore alone provides over 30-40% of India's total IT exports and employs half of its IT work force. If public policy alone could matter, geography of software in India would be different. Besides, many other regions in India are vying with Karnataka in attracting software industries but Bangalore alone continues to grow. Bangalore's export earnings are more than double that of its number two competitor.

The growth of software industry in India is a tribute to grass-root spirit of entrepreneurship whereby individual entrepreneurs have been able to exploit the fortuitous circumstances that have appeared due to the changing global Technology Cycles. The public policy driven market deregulation, however, has perfunctorily followed the burgeoning high-tech entrepreneurship, after having realized the future growth potential of new technologies for an economy such as that of India.

So called software export promotion measures at best made only a faltering start. The 1972 Software Export Promotion Policy which is cited as the first such policy enacted anywhere in the third world countries was in fact meant to be a bartering measure to compensate for foreign exchange spent on importing computer hardware. The initial rush of promotional policies was actually aimed at promoting exports from "export processing zones" set up in various parts, a policy that ended without significant gains. None of the policy measures at the initial stage were part of any grand design of making India software giant.

The software as a potential export-earning commodity attracted the attention of the government only after the Indian economy was hit by an unprecedented economic crisis in 1991. Throughout 1980s the Indian economy as a whole had remained unstable, imports & exports were erratic. The balance of trade deficit remained high, while the balance of payments deficit steadily worsened to several billion US dollars reaching a crisis point in 1991. During this period the only silver lining was the steadily increasing share of software export earnings.

Software exports had grown steadily reaching up to 40 per cent by 1991/92. The share of software exports in India's overall exports rose from just under 0.05 per cent in 1980 to over 1.8 per cent by 1994/95. Thus software exports grew faster during this period than other prioritized exports including textiles, gems and leather. Existing software companies registered an impressive growth and many new companies were set up during this period. Several companies such as Hinditron, Patni Computer Systems, Datamatics, Infosys, Wipro and Tata Burroughs Limited followed TCS in this segment. Apprehensions regarding efficacy of public policy measures for software export promotions were alleviated only after the publication of World Bank report in 1992.

The rapid strides made by Indian software industry may be attributed to the impact of global technology cycles and the Indian cultural milieu the dominant features of which provide conducive climate for mellifluous technologies of the present technology cycle. In each successive epoch these technology cycles leverage on specific type of socio-cultural settings, the dominant characteristics of which are in consonance with the nature of technologies, where they generate clusters of innovations. Technology is analogous to life processes. Historically speaking, the current phase of technology cycles is a corollary of large scale integration of multiple systems of technologies that has given rise to diverse streams of knowledge. The innovation of new mechanisms through synthesization of underlying knowledge base is the key characteristics of modern technologies. In the corporate context, nurturing diversity is critical for knowledge management and synthesization is crucial for leveraging knowledge for competitive advantage. Once embedded in harmonious socio-cultural environment the new technology cycles engender clusters of innovation and a new business cycle.

SOFTWARE AND INDIAN CULTURAL MILIEU

In order to explore the linkage between Indian cultural milieu and the current technology cycle dominated by software we need to understand what software is? Hardware models based on traditional industries that have only limited relevance to software, dominate current understandings of technological innovation and diffusion. The traditional understanding is constrained by machine paradigm. As software development is different from engineering and production work process it is vital to consider new paradigms.

Various approaches to software have certainly enhanced our understanding but none has been able to breakout of the traditional mode. It is useful to understand their inadequacy and explore how the traditional modes of thinking could be embedded in radically different paradigm. Thinking through the machine paradigm Eischen (2000) suggests an analogy between the software development and academic product. Analogy is quite poignant , yet it does not offer any space for concept of knowledge and concept of language. Eischen's other assertion regarding social model however is more useful. "Software models are being created from diverse fields that often model social, not natural process." Armour (2000), suggests software as knowledge storing device. But knowledge storage is only one of the functions of software.

Software is the essential medium for most forms of information flow and manipulation from natural to social to economic structures. Since, software is inherently a social product – it is limited and defined by both the social models that determine the algorithms as well as the inherently craft-structure of the software development process itself (Agre and Schuler 1997). In terms of algorithmic logic, software is embodied social knowledge. Since there are no universal laws of software development and because it embodies unique knowledge, the process tends to be arbitrary and crafted rather than defined and manufactured (Raymond 1999; Stephenson 1999; Kohanski 1998 cited in Eischen 2000). So much so that at times there could be even more than one algorithm for producing the desired outcome. This difference is the outcome of software designer's perceived reality of the domain knowledge as communicated by the system user. Mental processes that are determined by the socio-cultural milieu shape designer's perception. Therefore in true sense of the term software is an embodiment of a cognitive construct of perceived reality derived from the domain knowledge communicated by the user. Software consists of sequences of notations or language meant to communicate a specific message in a specified manner. In this sense, the design of software architecture is essentially the design of a communication system. The way the developer comprehends the user needs and embeds these in this communication system is conditioned by the socio-cultural phenomenon.

The communication problem in software development between IT professionals and system users is well-charted (Mumford 1972; Murray and Willmon 1993; Rubey and Farrow 1982 cited in Quintas 1991), however the treatment of software itself as a communication system is less emphasized. It is this aspect of software that is more liable to cultural cognitive patterns. Culture as a determinant factor is assuming greater significance in the study of software. As the demand for more strategic use of software and integrated information system increases, the knowledge from both philosophy and social sciences will become important (Hanseth 2001). When we consider software as a cognitive construct of social domain knowledge and the design of a communication system, two concepts assume significance in the new paradigm- the concept of knowledge and concept of language. India's intellectual traditions evolved through several millennia of ideational process offer the advantage of a uniquely compatible theory of knowledge and the linguistic system for those who operate in this cultural milieu. In the software development process two stages are most critical; the algorithmic stage when the designer embeds the perceived knowledge of the system user and coding when the knowledge has to be communicated to achieve desired result. Here the knowledge of linguistics, grammar and syntax assumes significance.

The Vedic philosophy of knowledge has developed yoga as an effective technology to explore inner and higher levels of reality in a subjective way. It does this largely by enabling the observer to change the type and center of his or her consciousness. Sri Aurobindo, distinguishes four different types of knowledge that are routinely used in the ordinary working state.

1. Knowledge by indirect separative contact (=scientific knowledge of the outer reality)
2. Knowledge by direct separative contact (=objective introspection of inner processes)
3. Knowledge by direct intimate contact(=experiential knowledge of inner processes)
4. Knowledge by identity (=Vedic knowledge)

Indian mind is intrigued by the inner workings of the physical world and the self.

Concept of soul and salvation is the central and enduring theme of Indian philosophical knowledge. Soul (the atman) which resides in every physical object is part of all pervasive energy (Brahman) that drives the entire universe. Thus soul is the cause of inner workings of all objects. Software is like an invisible internal energy, a driving force of all mechanisms. Knowing and being able to create software gives an Indian developer the thrill of knowing the soul.

The problem of knowing precisely the social domain knowledge of the system user is also resolved by the Indian developer through application of the knowledge by identity. Through his unique cognitive functioning an Indian developer makes knowledge by identity operational to a substantial degree. "It should not be surprising, however, if similar manifestations of the basic principle would be found to be fairly common (Cornelissen 2002).

The another critical stage in software development is coding, a technique of communicating the embedded algorithmic knowledge to perform desired functions. This process is highly dependent on speech act theory, linguistics, grammar and syntax etc.; An Indian developer is helped by the pervasive influence of Sanskrit language. Along with the philosophical thought, Sanskrit language was invented by the brahmanical class to express and communicate the deeper meanings of philosophy in subtlest form. Amongst all the world's languages Sanskrit has been rated to be the most computer friendly. The capability of Sanskrit language to express more in the least possible words helps Indian code writer to be economical in software development.

Here again, we are faced with the same question that if Indian culture is so congenial why software activity does not take place across all regions in the country with equal intensity. Deeper than the factors emanating from the public policy and cultural milieu, we need to look into the phenomenon more typical to Bangalore, the elements of which may lie in the unique intellectual ecosystem found in Bangalore. In order to grasp the significance of this ecology we need to understand various components of this ecosystem and historical antecedents of its evolution.

Industrial Clustering: Theories and Practice

The success of Silicon Valley has spawned multiples of its clones around the world. It has also drawn much scholarly attention theorizing high-technology clustering and deep interest among regional economic planners. A growing body of literature has already appeared focussing on factors responsible for clustering, the nature of industries that tend to cluster and impact of clustering on competition, regional economic growth and its relevance for developing economies. (Gertler 1995, Porter 1998). Krugman (1991) and Arthur (1994) have suggested that the harmonization of international market and reduction of transport cost has increased the importance of the proximate environment of a company.

Clustering is essentially, the process of development of locally rooted value–creating systems. Several companies at each step of a single value–chain, agglomerate in one nation or single region within a nation while serving the larger market. Clustering can happen because one value–creating system can impose itself at the beginning of an industry life cycle or because most companies of an industry, except the members of the strongest cluster, go out of business over time. An integrative approach, to understanding the conditions for clustering may be more rewarding. Steinle and Scheile (2002) offer a typology of clustering based on 'necessary conditions' (NC) and 'Sufficient conditions' (SC) and classify the clusters into two types, (i) localized sectoral agglomeration of symbiotic organisations, and (ii) coincidental agglomerations. In order to draw more fruitful lessons for the purpose of high technology based regional development and investment decisions, it may be useful to look at clustering process as 'endogenous' or 'induced'. In our analysis of Silicon Plateau, we propose to follow this perspective.

Clusters represent a confluence of various streams of economic development theory and practice, inter-firm Co-operation (networks), agglomeration (external economies), social capital (associative behaviour), and technology transfer and diffusion (knowledge spillover). They each contribute to a region's "collective efficiency" (Rosenfeld 2001). Spatial clustering has always contributed economic growth through enhanced learning processes. This proposition is receiving greater recognition only now as we shift toward a knowledge economy. It is being asserted that 'the localised cluster is the territorial configuration *most likely of enhancing learning processes*'. (Malmberg and Maskell 2001; Maskell 2001). (emphasis added) This proposition may be particularly relevant in the context of Software-based clusters such as Bangalore for the Software in most cases itself behaves like knowledge.

Silicon Plateau – Bangalore

Clusters of firms in related industries have historically coalesced around critical mass of business activity. High-Technology industries of the information era also appear to conform to this tendency (Bahrami and Evans 2000; Quah 2001). The rise of Bangalore's Silicon Plateau is remarkable in as much as it stands out as one of the successful high-technology clusters outside the US Silicon Valley while most other regional high tech clusters appear to be faltering. Despite remarkable resemblance with the original Silicon Valley of California Bangalore's Silicon Plateau have significant areas of divergence that set it apart from the whole of 'Siliconia'. Most other high-technology regions are located in the US and are a result of public policy initiatives. Bangalore is located in the so called developing socio-economic environment and the growth process, much like the Californian Silicon Valley, appears more "endogenous". Most other high technology regions, barring a few are essentially hardware engineering clusters, while Bangalore is primarily a Software haven. Bangalore has been the fastest growing region and the largest software-based cluster. It is indeed remarkable that a successful high technology cluster of such a scale has emerged in an environment that only three decades ago was known as a sleepy languid town - a "Pensioners" paradise. The entrepreneurial spirit and commitment to innovation have so far proven effective in producing unique services and products and high value added jobs.

Industrial clusters do not emerge out of vacuum. They have a history. Although the pursuit of historical origins may be a perilous scholarly exercise in terms of exactly identifying the moment when a region was born; yet it is useful in two significant ways. Firstly, the recognition of the concept of "path dependence" implies that multiple factors of growth evolve over a period of time to coalesce at a given point in history. It helps in situating the region in the larger context of socio-economic forces that would inevitably influence the formation of the industrial cluster. Secondly, it provides more knowledgeable guide to those who hope to spur regional economic growth effecting "instant industrialization" driven solely by the public policy measures.

In recent years several studies on software industry in Bangalore have been undertaken (Chakraborty and Duua 2001; Parthasarathy 2000; Srinivasan 2001; STEM 2000) but none of these have considered historical origins of any significance. Lateef (1997) has made but only a passing reference to historical origins of the Silicon Plateau without adequately linking the evolutionary process with the current phenomenon. Delving into the historical context of Bangalore's Silicon Plateau is significant in our understanding of the underlying phenomenon of a unique ecosystem prevailing in Bangalore. In order to be able to comprehend the rise of Silicon Plateau we need to identify various components of this eco-system. While several studies have examined specific industries on sectors (Freeman 1990) few have drawn attention towards the significance of unique "ecosystem" (Rogers and Chen 1990; Saxenian 1994) in sustaining the growth process. In this paper we seek to explore the unique "intellectual ecosystem" of the Silicon Plateau and describe some of its major components.

Historical Antecedents of Silicon Plateau Ecosystem:

Software clustering in Bangalore is deeply influenced by the socio-economic conditions prevailing in the region around Bangalore. This may well be a pleasant coincidence of history that the region around Bangalore–erstwhile Mysore State–has always had the benefit of having rulers and administrators who had great fascination for education, industry, engineering works and evolving science and technology. Prior to the British conquest, Tipu Sultan–the then ruler of Mysore–Bangalore region had "definite scientific leanings and he was always experimenting with new European weaponry". (Jayapal 2001, 38). Like a 'technology buff' (Narasimha 1999) he was curious about European inventions such as barometers and thermometers, and made vigorous efforts to promote the manufacture of novel devices in various cities of the state in areas often known as *Taramandalpet* (which may be aptly translated as Galaxy Bazar), one of which still survives to this day in the olden part of Bangalore and houses many small workshops and powerlooms. "These were the 'Technology Parks' of his day".

After the defeat and death of Tipu Sultan three significant developments occurred that impacted socio-economic milieu of the region around Bangalore. Firstly, the Mysore kingdom came under the control of local rulers of the Wodeyar dynasty. Much in the tradition of their predecessors, Haider Ali and Tipu Sultan, the Wodeyar rulers continued their interest in European technology and engineering projects of public welfare. In order to popularize basic technical skills among the local populace Wodeyars established a number of educational institutions. Second important development was the movement of British garrisons to Bangalore. Lying at about 900 metres above the sea level with its salubrious climate, natural bounties of Bangalore seem to have caught the imagination of the British military brass-tacks. Having established their supremacy in the region, British decided to build one of the most spectacular cantonments in Bangalore. They poured their heart into it. Being built at the pinnacle of British imperial power British employed state-of-the-art techniques and technologies in planning and building infrastructure for the Bangalore cantonment. In the British India modern technology flowed along the course of military cantonments. "Cantonments were a place created as small European cosmos" (Veena Talwar Oldenburg 1989 cited in Jayapal 1997, 51). Residual knowledge of modern science and technology thus got embedded in the local socio-economic milieu. A cumulative effect of cantonment culture is strongly felt on the Bangalore metropolis even today.

Thirdly, nineteenth century was a period of great ferment in Indian society. Under the impact of British liberal education a number of social reforms and cultural revival movements sprang up across the country. Along with this arose a powerful movement for cultivation of western science and technology and its adoption in India. Because of the region's historical experience in the spread of education and technical skills the educated elite was immediately drawn towards these centers of scientific, industrial and technological activity. India's first Nobel laureate Sir. C.V.Raman was a product of this ferment. He later became the first Indian Director of the Indian Institute of Science.

Important outcome of this social ferment was the wide spread acceptance of education as the means of deliverance. With a view to challenge the brahmanical dominance in society several intermediate castes such as Vokkaligas and Lingayats created their own Mutts (the religious Academies) headed by a Swamiji who commanded a great influence in their respective communities. These Mutts took lead in community education and established hundreds of institutions at various levels. Maharaja of Mysore who was seriously committed to the promotion of science, technology and industry unveiled a new plan for industry and technical education at the Mysore Economic conference in 1911. The economic policies pursued by the Dewans of the old Mysore State, some of whom worked under the credo "industrialize or perish" created an environment for technical, scientific and industrial growth. Bjorn Hettne has described this period as a "fascinating experiment in economic development" in Mysore State (Bjorn Hettne 1978 cited in Kaul 1993). A significant aspect of economic policies pursued throughout this period was the emphasis on promotion of entrepreneurship and private participation in industry and education.

As a result of such proactive policies a large number of industries in small and medium sector were established. Mysore's industrial production reached a peak around 1940. Second World War benefited Mysore State as all its production capacity was fully utilized. All indigenous industries expanded to the extent that they were not dependent on imported inputs. As a direct result of the war production of ammunition increased considerably, and the Hindustan Aircraft Industry was started. The Silk Industry also benefited from the manufacture of parachute cloth and silk sewing thread for war purposes. (Kaul 1993; 95). Thus a favorable climate for industrialization, scientific and technical progress and private enterprise had been created in the Mysore State prior to independence.

Indian Institute of Science:

Today the Indian Institute of Science is rated as number one among the most innovative institutions in the Asia-Pacific region. Established through an endowment made by Sir Jamshydji Tata in 1886, the private involvement in education was not all commercial. Founding of the institute had a dramatic effect on local industrial, technological and scientific activity. The Institute became a centripetal force providing nucleus for synergy amongst the industry, science and technological research, particularly during its formative years.

It is remarkable that at an early stage interdisciplinary approach was adopted in the teaching methodology and synergistic approach in research. Right from the outset the Institute was conceived to provide supports to the local industries and help create new industries.

In 1913, Sir M.Visveswaraya, the new Dewan of Mysore, was nominated to the council of the Institute by the government of Mysore. His association with the Institute had its impact on the applied researches. A striking feature was that a substantial number of research scholars of the Institute secured appointment in several industries, private firms and other research institutes. (Subbarayappa 1982).

Aeronautical Engineering:

It was during the Second World War that Bangalore developed a nucleus for this industry. When the British Royal Airforce base at Singapore came under Japanese attack, the RAF was forced to relocate these bases and Bangalore was identified to be an ideal location. It was in 1940, Walchund Hirachand, an industrialist, had set up in Bangalore a factory primarily for automobiles. The compulsions of World War II led this factory to be transformed into the Hindustan Aircraft Ltd., for assembly and repair of airplanes. The Indian Institute of Science received Rs. 1 lakh along with a recurring grant to set up the Aeronautical Engineering Department. Thus a new window to the high-technology frontier was opened in Bangalore. Aviation technology is a complex mechanism of large-scale integration of multiple systems of technology. Through a network of allied industries, Hindustan Aeronautics Ltd., provided a centripetal nucleus for the concentration of varieties of skills around Bangalore.

Unique Intellectual Ecosystem of Silicon Plateau:

The rise of Silicon Plateau in Bangalore owes in large part to the unique intellectual ecosystem found in the region. Congenial elements of Indian cultural traditions and the public policy measures have certainly enhanced the interplay of various components of this ecosystem. Stimulated by various factors, the systematic development of science, technology, industry, educational institutions before the independence laid the foundation for the transformation of Bangalore into a Science City.

Independent India's first prime minister Jawharlal Nehru had an overriding influence in all matters concerning nation building particularly the industry, science and technology. He was enamoured by Bangalore and had a vision for Bangalore as the "City of the Future". He saught to turn it into Indian Intellectual Capital (Stremlau 1996, 157 cited in Lateef 1997). Starting with the Hindustan Machine Tools, which Nehru called the "Mother Machines", Bangalore soon became the major centre of heavy industries in the public sector. Heavy industries characteristically tend to use complex technologies, which generate constant demand for integration. When the production activity in these industries gained momentum demand for integration technologies – electronics and computers increased correspondingly. Soon Bangalore transformed into an electronic city.

Sino – Indian war and subsequent two wars spurred a new industrial activity in Bangalore. Major burden of supplying, manufacturing or assembling fell on the heavy industries. Apart from expansion in productive capacity extensive innovation in design and development activity was carried out to support India's upcoming armament industry. Another direct impact of growing defense requirement was the explosive expansion of Defense Research and Development Organisation, which consolidated the research, development and manufacturing of defense-related electronics. In a short span of time research labs were set up for the development of missiles, aircraft, aero engines, combat vehicles, electronic warfare system, high explosives and under water weapons. Necessary facilities were created for encryption, decryption war gaming and training of service officers in modern warfare technologies. The establishment of research organizations such as the Centre for Artificial Intelligence and Robotics, ISRO Satellite Research Center has pushed the frontiers of scientific research to the cutting edge and added to the complex of Bangalore's knowledge ecology. One of the outcomes of this concentration of heavy industries, electronics and research organizations in Bangalore was the formation of backward and forward linkages. There were many upstream and downstream activities that emerged to support these industries and were linked to electronics in some way. One of the significant outcomes of this clustering has been the large-scale talent migration to the city from all over the country. Apart from rendering a cosmopolitan character to the city culture a critical mass of knowledge pool has been constantly added to the intellectual eco system. A powerful component of this knowledge pool comes from the migration of thousands of professionals every year who settle down here to spend the twilight years of their lives since Bangalore has been known as a 'Pensioners Paradise'. This diverse pool of knowledge resources has given birth to a strong community of consultants. Cementing the production networks among diverse industries, R&D organizations, through their professional work, the consulting community has been an effective vehicle disseminating mature knowledge across the industries and institutions.

Educational infrastructure is perhaps the strongest component of this self-rejuvenating eco-system of the Silicon Plateau. Bangalore has had a long tradition of being a major centre of learning and education. As early as in 7th – 8th centuries, when most of the medieval world was reeling under the Dark Ages the region around Bangalore had a number of flourishing educational centres known as *agraharams*. Maharajas of Mysore promoted private participation in education and various Mutts played leading role. As a result, Bangalore region has highest number of educational institutions comprising nearly 100 engineering colleges, 40 medical colleges, hundreds of polytechnics and specialized institutions. Bangalore is now fast becoming a major centre of international schools. Karnataka produces nearly 100,000 engineering graduates in various disciplines. Karnataka was the first state to have allowed private participation in higher education the benefits of which are clearly seen in the form of finest institutions in the country. An another significant dimension of private ownership of educational institutions has been their propensity to respond to emerging demands of the industry. Consequently, engineering colleges in Bangalore region offer many such courses not found elsewhere in the country. This is the most potent source for self-rejuvenating process of Silicon Plateau's intellectual Eco-system.

The dominance of Mutts and Swamijis has had positive influence in providing continuity with Indian philosophy of education the value system of which has flowed through Vedic period. The Mutts and Swamijis belonging to intermediate castes had risen on the anti-Brahmanical plank, they did not breakout of the brahmanical order. Instead, in their attempt to displace Brahmins from their social position they claimed themselves to be the true followers of Vedic value system, thereby superior to Brahmins, and preserved the brahmanical order. Synthesization of multiple streams of knowledge is the dominant theme of Vedic philosophy. "It is not enough merely to interpret reality as perceived by the senses; it must explain both sides of reality, the change and the unchangeable, being and becoming, permanent and impermanent, animate and inanimate. All these conditions have been satisfied by the philosophical systems of India". (Bernard 1957 cited in Varma 1969).

Social lifestyle of Bangalore is often cited as one of the important factors attracting various MNCs. The free social life dotted with bars and pubs, galleries and design studios, fashion houses and concentration of artists, designers, scholars lend somewhat Bohemian character to the city. Much of this culture owes it to the cantonment period of British garrisons in Bangalore.

When Texas Instruments set up its design and manufacturing facility here little was known about Bangalore's potential to support a high-tech cluster. However, TI's move made the world notice Bangalore. But when Infosys decided to move its headquarters from Pune to Bangalore and WIPRO shifted its emphasis from hardware to software floodgates opened for companies to set up their shops. The government soon caught up with the idea of software and Bangalore transformed into the Silicon Plateau of India. The government of Karnataka was quick to react to the new changes in the economic environment and created enabling environment to attract and promote software activity.

We conclude that this unique eco-system of the region provides a fertile ground for start up firms and fuels spectacular growth trajectories. Tapping into this versatile eco-system enables firms to obtain increasing returns, which in turn attract even larger number of firms.

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5

SINO-FOREIGN JOINT VENTURES AS EXOGAMIC PARTNERSHIPS

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INTRODUCTION

The 'Open Door' policy and the so-called 'Four Modernizations' launched by Deng Xiao Ping more than twenty years ago created an entirely new departure for China after the turmoil of the cultural revolution. China was able to attract substantial foreign direct investment (FDI). It is today by far the largest recipient of FDI amongst emerging countries. This has been the starting point of significant opportunities for foreign and Chinese firms. Some early entrants (such as Alcatel, Volkswagen, Citroën or Schneider) have been able to create sustainable competitive advantages in several industries. The 'Open Door' policy gave an impetus to rapid transformations and an astonishing dynamic in the Chinese so-called "socialist-market economy". Even if the GNP growth rate (seven percent in 2001) no longer reaches ten percent (as was the case in the eighties), it is still far ahead of Western economies. More recently, China's entry into the World Trade Organization (WTO) in 2001 might be the catalyst for a renewed dynamic. These new regulations will probably enhance opportunities and reduce political and economic risks. This new framework should also alleviate some strong regulatory barriers. It should facilitate technological, commercial and financial transfers in the future. China's entry into the WTO thus constitutes a major reshaping of the competitive landscape. It reinforces the attractiveness of this emergent country for foreign entrepreneurs as well as more traditional companies. It also calls for a better understanding for business leaders on how to do business in China.

Joint ventures with local partners have been the dominant pattern for doing business in China. Nevertheless, because of changes in government policy and the disappointing performance of some joint ventures, a few sectors recently experimented with a number of fully-owned organizational arrangements (Vanhonacker, 1997, 2000; Deng, 2001). Obviously, wholly foreign-owned enterprises give more flexibility and control to the owner. But at the same time, these arrangements offer a weak interface with the local context and greater risks because of operating alone. The new entrant is particularly vulnerable to indigenous conditions.

This text is focused on the explanation and the design of Sino-foreign joint ventures. The aim of this paper is to demonstrate that Sino-foreign joint ventures are **exogamic partnerships**, i.e. inter-firm alliances between partners exhibiting unrelated resource profiles, pooling idiosyncratic sets of resources in the joint venture and trying to capture knowledge from the counterpart.

Three types of questions such are raised: a) What is the nature of the joint action, i.e. the stages of the chain of value, usually taken by these co-operations? b) What does each partner respectively bring to the cooperation? Sino-foreign joint ventures are supposed to mix different resources: technology and management expertise from the foreign partner and country-specific knowledge and assets from the Chinese. Is this true? What does technology cover in these deals? What factors underlie this local knowledge of Chinese companies? c) What are the determinants of these types of cooperation? What are the companies which engage in these alliances looking for? What benefits can foreign companies draw from such alliances? And Chinese companies? Are the expectations of each party different?

This paper is structured in five parts: Part 1 offers a theoretical background to the Sino-foreign joint ventures. Part 2 depicts the conceptual framework – centred on the dichotomy between endogamic and exogamic partnerships. Part 3 lists the hypothesis of the research. Part 4 explains the research methods employed. Part 5 presents the results and discusses the findings.

THEORETICAL BACKGROUND TO SINO-FOREIGN JOINT VENTURES

This research on Sino-foreign joint ventures relies on several very long-lived theoretical streams rooted in the alliance literature. However, the emergence of resource based approaches and recent developments on the transfers in alliances between firms, have shed new light on the question of knowledge transfers in international joint ventures.

The theory of inter-firm alliances

Inter-firm alliances and co-operations differ from other organisational forms of relations between firms on at least four points (Jolly, 2002): (a) they are concluded by at least two sovereign firms to undertake joint action and thus to share control and decision-making powers, responsibilities, information, profits or losses. They jointly define the strategy of the business and together assume the risks on a given perimeter and for a given period; (b) such alliances imply the pooling or the exchange of resources, i.e. of human resources, technological competences, physical assets, industrial capacities, organisational know-how, reputations, commercial or marketing capacities, etc.; (c) they suppose that the partner companies will obtain more advantages than if they were operating alone: such advantages as size or scale through the accumulation of similar resources (endogamies) or symbiotic advantages through the combination of differentiated resources (exogamies); (d) these alliances require that the allies remain independent, preserving their identity outside the alliance, i.e. on activities which are not within the field of co-operation.

The equity joint venture (or "joint subsidiary") is a legal and distinct organisational entity for a joint action generally created by two or three independent firms through the transfer of part of their respective resources. The parent companies hold a fraction of the equity as a function of their respective contributions (generally shared in a relatively egalitarian way). They exert collective control, independently or not of their share of participation. They are remunerated for all or part of their contribution according to the profits generated by the entity.

The resource based theory

According to Barney (1991), "firm resources include all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness" (p. 101). It is traditionally assumed that each competing environment has its own key success factors and that each firm seeks to develop resources allowing it to satisfy these. As a consequence, all the firms tend to develop the same portfolio of resources. Resource based strategies (Wernerfelt, 1984; Prahalad & Hamel, 1990; Grant, 1991; Stalk *et al.*, 1992; Leonard-Barton, 1992; Prahalad, 1993 – to quote only the first authors) led to an inversion of this orthodox framework of strategic analysis. These new approaches hypothesize that the scarcity of a resource creates revenue for the enterprise which holds it (patents, access privileged to a natural resource, world distribution network, etc.); as a consequence, heterogeneous portfolios of resources generate distinct performances and imperfect mobility of resources impedes the duplication of revenue by competitors. By the way, it is assumed that there are economies of accumulation: those companies which first manage to reach a high level of resource increase this level at a lower cost than their competitors.

The interest in resource based strategies exacerbated the sensitivity towards these questions. The company that decides to enter or to expand its activities in a foreign country needs to access specific resources: distribution channels, human resources, supply networks, etc. The development of the Chinese economy also calls for the import of resources, most importantly new technologies. As a consequence, each side of a Sino-foreign joint venture has a resource gap to fill.

However, this cannot be done easily, because these resources also have a competitive value. In this context of primacy of resources on the competitive game, firms put the emphasis on having exclusive control of resources that are rare, tacit, durable, not easily imitable, extensible, serving multiple fields, etc. As such, the resource based framework helps better to understand why managers attach so much importance to the control of the resources pooled into Sino-foreign joint ventures.

The learning theory in inter-firms cooperation

Beyond the well-known size and symbiotic effects resulting from cooperation, several authors like Kogut (1988), Doz, Hamel & Prahalad (1989), Hamel (1991), Richter & Vettel (1995), Mowery *et al.* (1996) showed that working jointly makes it possible for each partner to learn from the other. From this perspective, the alliance is a mechanism through which knowledge, competences or technologies are acquired while working with partners. Through co-operation, a partner can appropriate a particular type of resource brought by the ally provided he possesses mechanisms adapted to this transfer. A joint venture appears as an osmotic zone between two organizations where elements of knowledge are forwarded: this can be technological or other knowledge (e.g. marketing information), expertise, know-how, competences in a given field (e.g. manufacturing competences), etc.

Knowledge is, by nature, more or less easy to include/understand, transfer and finally to duplicate (Inkpen, 1996). An alliance is a suitable vehicle for the transfer of tacit knowledge, i.e. of inarticulate knowledge, difficult to formalize explicitly and, by definition un-codified or un-codifiable. Examples are intimate knowledge of a market (or a country), or expertise in a management method endogenous to an organization.

Contrary to a wide-spread idea, Sino-foreign joint ventures are far from being an alternative to competition; quite the contrary, competition is maintained even within the core of the alliance itself, but this competition exists on different grounds from usual. Because of the dynamics of exchange of intangible assets, knowledge, know-how, competences, expertise, etc. that occurs in these joint structures, Chinese and foreign companies are engaged in a fight to appropriate the counterpart resources; consequently, the victorious ally is the one which is the first to capture the resource of the other.

CONCEPTUAL FRAMEWORK

Two archetypes of inter-firm alliances

In the interpersonal sphere, endogamy is the union of two partners coming from the same social milieu; exogamy is the marriage of two people originating from different backgrounds. In the business world, the concept of social milieu is replaced by the industry in which a company operates, as well as the products and/or services it delivers (see Table 1).

Joint research and development (R&D) between companies from the same industry is an example of endogamy, as is a factory built by two car manufacturers to produce, say, a common engine, gear-box, power-train or platform. There is a good chance that the partner profiles share certain similarities – for at least three reasons. First, they operate within the same environment, with the same customers, distributors, and suppliers. Second, they have to play by the same rules so the key success factors will almost certainly be comparable. Third, if they share the same background, they might have very similar value chains, technology portfolios, manufacturing facilities and distribution channels.

By contrast an exogamic alliance usually involves two companies from different industrial backgrounds. One example might be a car manufacturer setting up an alliance with an aluminium producer to jointly develop the use of that metal in the auto industry. The two partners will not have common suppliers, distributors, or customers. They will have completely different value chains, different technologies, different manufacturing capabilities and different types of marketing expertise.

In some circumstances, of course, companies belonging to the same business sector can develop different resource profiles and therefore enter into exogamic alliances. Alliances between well established, large pharmaceutical companies and small dedicated biotechnology companies are a case in point. The two belong to the same industry, hire the same kind of people, face the same regulation bodies, etc. Nevertheless, their profiles differ sharply: they do not share the same size, the same type of ownership, the same history, etc. The big company usually puts the emphasis on procedures and tools while the start-up relies heavily on people. But, these two types of company enter into joint ventures because the start-ups usually possess specialist technology but lack manufacturing capacity, notoriety and a distribution network, whereas big companies often have the opposite competitive profile.

	Endogamy	**Exogamy**
Allies' environments and value chains	Related	Unrelated
Resources brought by allies	Similar, same nature, substitutable	Differentiated, specific, idiosyncratic, non substitutable
Common action	Accumulation of identical resources	Combination of differentiated resources
Effects produced by pooling resources	Size, scale, volume, market power, etc.	Symbiosis, interbreeding
Impact on competencies	Strengthening of existing competencies	Construction of new competencies
Benefits of cooperation	Quantitative complementarities: - reaching a critical mass; - reaching the optimum scale; - gaining scope economies; - increasing joint economies of scale; - spreading risks amongst members.	Qualitative complementarities: - uniting buyer/seller; - combining different types of knowledge or competencies; - uniting separate lines of products or services; - merging distinct geographical territories.

Table 1 – Contrasting the two archetypes of inter-firm alliances

Accumulating similar resources or combining differentiated competences. As soon as two companies share related profiles, have related assets, capacities, abilities, competencies and types of expertise, there is a high probability that they will pool similar resources in their cooperation. For example, if they decide to jointly research a new technology they will most likely bring together engineers with similar backgrounds. If they intend to merge their supply functions, the buying skills on each side will certainly be alike. And if they decide to build a joint factory the manufacturing experiences will be close in nature. In such cases the only aim that can be pursued by allies is the accumulation of identical resources.

On the other hand, when two companies differ significantly in terms of profile, the pooled resources will be highly differentiated. When each partner contributes resources that cannot be brought by the counterpart, the result is that resources pooled in the cooperation cannot be substituted. In such circumstances, the allies are not looking to accumulate similar resources, but to combine differentiated resources.

To conclude, partners of an endogamy can only pursue quantitative complementarities whereas exogamy can only deliver qualitative complementarities. Looking for quantitative complementarities in exogamy is unrealistic. The resources pooled are too different to produce scale effects. In the same vein, looking for qualitative complementarities in an endogamy would be inappropriate as the resources brought by the partners are likely to be fully substitutable. offers a summary of our main arguments.

HYPOTHESIS

The core proposition of this research is that Sino-foreign joint ventures are exogamic partnerships. Four hypotheses were formulated.

Profiles of the parent companies

The question of the similarity / dissimilarity between partners in joint ventures is an important one. Endogamy tends to reduce intercultural and inter-organisational problems because of a similarity of profiles. Exogamy, on the other hand, is exactly the opposite – because the allies' environments and value chains are unrelated. Chen & Boggs (1998) showed that perceptions of cooperation are more favourable when joint venture partner firms are from culturally similar countries.

Parent companies of Sino-foreign joint ventures obviously come from unrelated environments. They originate from different countries, with different histories, notoriously different economic, political and legal backgrounds, different values (e.g. individualism vs. collectivism), profoundly different languages, distinct social norms, cultures and traditions,[1] etc. Even if they belong to the same industry, it seems reasonable to assume that Chinese and foreign companies exhibit different profiles as well as different expertises etc. I hypothesized the following.

> ***Hypothesis # 1:*** *Partners of Sino-foreign joint ventures exhibit unrelated morphological profiles.*

Resources brought by the partners in the joint venture

Because many plants were outdated, and technologies frequently needed to be upgraded, and because management skills were weakly developed in Chinese state-owned companies, the Chinese government decided twenty years ago to rely on foreign direct investment to establish an in-flow of technology and management expertise. Previous research tends to demonstrate a specific pattern of resources distribution where each partner specializes in its own set of contributions to the joint venture:

- A case study of four Sino-American joint ventures conducted by Yan & Gray (1994) with both the US and the Chinese partner shows that: "the foreign firms contributed more heavily than their local partners in the areas of technology (product design, manufacturing know-how, and special equipment) and global support (technical, marketing, and maintenance services), and the Chinese firms contributed more in the areas of knowledge about and skills for dealing with the local government and other institutional infrastructures." (p. 1492);
- Relying on his experience, Vanhonacker (1997) made similar assumptions about foreign expected contributions to joint ventures;
- Relying on a case-based approach, Luo (1998) offers a comprehensive list of the attributes (strategic, organisational and financial) that the local partner should hold. These include resources such as marketing competence, i.e. some distribution channels, relational attributes (*guan xi*), market power, experience of the industry, etc.;

[1] For example, Western managers are trained to think in terms of exclusive choice (A or B) while, in China, culture favours duality (A and B at the same time).

- A study carried out in thirty-five major Sino-foreign joint ventures by Liu & Pak (1999) shows that big multinationals are exporting their marketing techniques and concepts to China as well as a standardized brand policy. On the other hand, distribution channels, promotion and market segmentation tend to be localized – and, as such, are provided more often by the Chinese partner;
- A qualitative research based on eight in-depth case studies of Sino-French joint ventures (Jolly, 2001) suggested that each partner contributes to the joint venture with differentiated assets. To put it simply, each partner enters the bargaining process to form the joint venture with its own specific advantages that cannot be substituted.

The very specific case of *guan xi*, often mentioned in the literature, needs some explanation. The combination of the word 'guan', which means 'door', with the word 'xi', i.e. 'to tie up', covers the social and political connections with influential people required to make business run smoothly. It takes time to cultivate *guan xi*. In Western terms, it is close to the concept of 'networking'. Benefiting from *guan xi* means having support, favours or assistance, getting information from someone; but, *guan xi* also means that you should be able to deliver those same advantages when called upon to do so. This type of link originates from birth at the same place, study in the same university, professional or familial relationships (Ambler, 1995). In a modern economy, *guan xi* is not in line with market mechanisms; it can even hamper competition – it may create favouritism in the selection of new employees or in the allocation of contracts for suppliers.

A joint venture allows a foreign company to benefit from the *guan xi* of the managers of its Chinese counterpart (who usually originate from a state company) – especially when it comes to non-market issues, for example, getting administrative authorizations (to get approval to form the joint venture, to build a factory, to recruit staff from outside, etc.) or achieving political advantages. This point is highly sensitive as the communist government plays a prominent role in China. It has been shown by Osland & Cavusgil (1996) that the host government has a strong influence in the performance of international joint ventures. For example, state-owned firms are the most likely partners for foreign companies. Powerful government regulative action and the close involvement of government agencies in business affairs was also stressed by De Bruijn & Jia (1997).

Hypothesis # 2: *The Chinese and the foreign partners combine differentiated resources under their specific control within the joint venture.*

(2a). Chinese partners are assumed to bring country-specific knowledge or assets, i.e. land, buildings, access to utilities, access to work force, access to distribution networks, and guan xi with the business community and government authorities;

(2b). Foreign partners are assumed to bring product technologies, process technologies, managerial abilities, production equipment and capital.

Learning objectives of each partner

Not all joint ventures are built to give learning opportunities to the partners. Only exogamic partnerships allow partners to learn from each other. This cannot be the case in endogamic partnerships because partners have similar profiles and, as a consequence, there exist few opportunities to learn from each other. In the case of endogamic partnerships, the only thing possible is to learn together, to produce new collective knowledge. Endogamies do not favour learning from each other. This is the same argument that authors, such as Liu & Vince (1999), made about Sino-foreign joint ventures: differences between partners are a source for learning.

It is a common argument that China's strategy is to rapidly catch up with the outside world in a range of advanced technological sectors. As a consequence, it is assumed that primary motivations for a Chinese company in entering a joint venture are (1) to gain access to advanced technology, modern plants and equipment and new product models as well as (2) to gain access to modern management techniques, systems, styles and expertise (Beamish, 1993; Yan & Gray, 1994; Osland & Björkman, 1998; Si & Bruton, 1999; Deng, 2001). According to De Meyer (2001), there is even an increasing expectation and demand emanating from Chinese authorities concerning technological transfers for transferring the latest, the state-of-the-art (rather than established) technologies. It should be stressed that transferring technologies might be a concern for foreign companies as soon as these technologies are sources for competitive advantage. Transferring new management techniques from the West is one way of improving practice in local companies. This point was demonstrated for HRM techniques by Ding et al. (2000). Their case-based research was conducted in sixty-two industrial enterprises – half state-owned, half joint ventures with foreign investment. It shows that there are wide variations in HRM practices in Chinese enterprises of different ownership types: state-owned companies are less-market oriented than joint ventures (they are subject to organizational inertia – especially the largest); on the contrary, joint ventures are places where modernization tends to be adopted. This means that foreign investment has a positive impact on HRM practices in Chinese enterprises.

Less attention has been paid to what foreign companies can learn. A generic expectation for foreign companies is to facilitate their entry and to learn how to do business in China – a complex, highly regulated, volatile and uncertain environment. A survey conducted with 200 British companies by Zhao *et al.* (1997) shows that the compensation for technological transfers is gaining access to the Chinese market. Research conducted by Calantone & Zhao (2001) hypothesized that the foreign partners motivation for forming a joint venture in China might be summarized in three words: efficiency, competition, and learning. Efficiency covers using the Chinese partner's resources, overcoming government restrictions, and reducing risk with unfamiliar markets. Competition relates to enhancing market power. Learning is about knowledge of the local market, culture, institutional characteristics and other site-specific information.

Tsang (1994) particularly emphasized what he considered to be the greatest challenge to expatriates working in China for foreign investors in Sino-foreign joint ventures: the management of the Chinese workforce, including both workers and managers. The Human Resource Management (HRM) functions are well known (recruitment, remuneration, promotion, training, etc.) but the institutional and cultural context of operation in China is notably different from that of foreign countries. Joint ventures have to deal with the heritage of state-owned enterprises. In China, overstaffing, unwillingness to take risks and egalitarianism were the rule in state-owned companies. Until the 1994 labour law of the PRC, employees of state-owned enterprises were virtually immune from dismissal thanks to the so-called 'iron rice-bowl' (*tie fan wan*) which ensured jobs for life (Ding *et al.*, 2000). Because of the considerable power of administrative bodies, the labour market is still far from being free; and skilled managers and professionals are very often in short supply.

In summary, the aim of foreign investors is to gain market access to China, to learn about the political and regulatory environment (which may well differ from one province to another!), to learn to manage the Chinese workforce, to learn about cultural differences between Chinese and foreign companies and to learn about the country itself (there are tremendous differences between rural and urban areas, between the coastal and inland regions, between Special Economic Zones (SEZ) and elsewhere, and significant differences between the North and the South).

An opinion survey conducted on a panel of forty-two Chinese executives (Jolly, 2001) discloses that there is symmetry between the advantages sought-after by one partner and the contribution of the other to the joint venture. I hypothesize that:

> ***Hypothesis # 3:*** *Learning is not a one way process. The Chinese and the foreign partners establish cooperation in order to learn from each other, to understand and gain new insights. There is a symmetrical relationship between the learning objectives of one partner and the resources brought into the alliance by the other: each one is trying to appropriate what the other pools into the joint venture.*

Benefits gained through the cooperation

When two companies decide to pool resources in a joint venture and decide to work together, it is obviously because they want to benefit from this cooperation. Explanations for cooperation have been given by many authors (see e.g.: Kogut, 1988; Hennart, 1988; Osborn & Baughn, 1990. It is possible to distinguish between two broad families of explanations (Jolly, 2002), i.e. (1) explanations which emphasize the search for **quantitative complementarities**, such as: gaining scale economies, gaining scope economies, increasing negotiation power *vis-à-vis* suppliers, reaching a critical mass or sharing the financial burden; and (2) explanations which emphasise the search for **qualitative complementarities**, such as: combining different types of knowledge, combining dissymmetrical assets or gaining symbiotic effects. I hypothesize that:

> ***Hypothesis # 4:*** *Sino-foreign joint ventures are established in order to produce qualitative complementarities rather than quantitative complementarities, i.e. to combine different types of knowledge, to combine asymmetrical assets, to generate symbiotic effects, to reduce transaction costs.*

METHODS

Research design

Figure 1 gives a sketch of the overall design of this research, i.e. the variables and hypotheses between these variables.

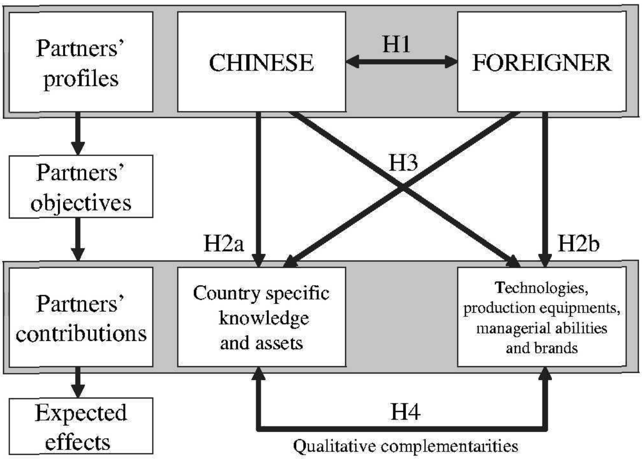

Figure1–Research Design

Data sources

Data collection was based on interviews conducted with general managers in Sino-foreign joint ventures with a minimum of one hundred employees. A semi-structured questionnaire was designed mixing closed and open questions. The questionnaire was divided into six sections: 1. description of parent companies; 2. profile of the joint venture; 3. resources pooled by partners; 4. objectives of partners; 5. expected benefits from cooperation; 6. management of the joint venture[2]. Experts on Chinese business were asked to review the questionnaire. An English and a Chinese version of the questionnaire was used[3].

Sample and respondents

A total of 67 questionnaires was collected. The major characteristics of the firms in the sample are shown in tables 2 and 3.

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[2] This last point is not considered in this paper.

[3] A copy of the questionnaire is available from the author on request.

A large majority (86%) of the Chinese partners of the joint ventures in this sample are based in the Shanghai area: 51 in Shanghai and 7 in adjacent provinces. Foreign partners come mostly from North America and Europe, particularly France and Germany. Only one foreign partner is from Singapore; none are from Taiwan or Hong Kong. This means that this sample is practically unbiased by overseas Chinese companies. Ownership is strictly balanced (50/50) in only twelve cases in the sample. Most of the time, the foreign partner is the dominant one (23 + 16 > 5 + 6). On average, the foreign partner holds 57% of the share (with 43% for the Chinese partner). Nevertheless, more than one third of the joint ventures (5 + 16) exhibit a significantly unbalanced ownership distribution, i.e. where one of the two partners owns more than 60% of the shares.

	Categories		n	%
Origin of the Chinese partner (n = 67)	Shanghai		51	.76
	Adjacent Provinces	Jiangsu, Anhui	7	.10
	Beijing		7	.10
	Other Provinces	Hubei, Yunnan	2	.03
Origin of the foreign partner (n = 67)	North America	(USA, Canada)	19	.28
	Western Europe	France	19	.28
		Germany	10	.15
		United Kingdom	4	.06
		Others	9	.13
	Asia	(Japan, Australia, Singapore)	6	.09
JVs equity distribution (n = 62)	Chinese partner over 60%		5	.08
	Chinese partner between 50% and 60%		6	.10
	Balanced ownership (50/50)		12	.19
	Foreign partner between 50% and 60%		23	.37
	Foreign partner over 60%		16	.26

Table 2 – Sample profile: Origin of partners and shareholding

Regarding size – as already mentioned, there is no joint venture in this sample fewer than one hundred employees. Most of the companies included are small (100-500) or medium-sized companies (500-2000). The average staffs is 907 employees – of whom 875 are Chinese and 33 expatriates, i.e. only 3.8% of the staff comes from abroad. Similar results are shown by data on turn-over (Pearson correlation = .643**). The sample includes joint ventures from the very beginning of the 'Open Door Policy' (1983-1990) as well as early followers (1991-1995). Some other companies were also created more recently. The average duration of operation is seven years. Not surprisingly, age is correlated with staff (Pearson correlation = .453 **). In summary, most of the companies in the sample have significant experience of doing business with a partner.

	Categories		n	%
Size of the JV (n = 66)	Small	100- 500	39	.59
	Medium	500-2000	18	.27
	Large	Over 2000	9	.14
Turn-over of the JV (per year) (n = 58)	Small	Less than 10 million euros	12	.21
	Medium-Small	10-100 millions euros	28	.48
	Medium-Large	100-1000 millions euros	13	.22
	Large	Over 1000 millions euros	5	.09
Date of creation of the JV (n = 65)	Between 1983 and 1990		7	.11
	Between 1991 and 1995		31	.48
	Between 1996 and 2001		27	.41

Table 3 – Sample profile: Companies size and age

It is worthwhile noting that this data collection relies mainly on the perceptions of Chinese managers (56/67) whereas most of the research done in the past has relied on foreign perceptions.

Measures and variables

Relatedness between the profiles of the Chinese parent and the foreign parent was analysed for thirteen distinct morphological items. The construct relies on the works of Galbraith & Kazanjian (1986), Ramanujam & Varadarajan (1989) and Very (1993). These include the organizational structure, size, shareholding, technology portfolio, R&D expertise, etc. of the parent companies, plus an "overall relatedness" rating. Measurement was made on a five point scale; from 'one' if the partners profiles were totally unrelated to 'five' if the companies had very close profiles.

Resources pooled into the joint venture were described with twenty-one detailed items split into six broad categories (Grant, 1991): financial resources, physical assets, human resources, technologies, managerial skills, marketing abilities.

Relying on the framework produced by Si & Bruton (1999), partners' objectives were described using fifteen different items, such as: answering government pressures, building relationships with local suppliers, gaining access to product technologies, etc. Partners were also asked to give their opinion on eleven different items describing the benefits to be gained from the cooperation. Several control variables were also used: the type of activity accomplished by the joint venture was evaluated through an open question; the size of the joint venture was measured with two different approaches: the number of employees and its turn-over; the shareholding distribution was measured with the share (in %) of the equity of the joint venture held by each partner.

RESULTS AND DISCUSSION

I examine hereafter the empirical results of this research regarding the four hypotheses that were formulated.

Hypothesis # 1: Profiles of the parent companies

Table 4 exhibits a summary of the data collected for the analysis of the relatedness between parent companies' profiles (Chinese on one side, foreign on the other). The first column of the table lists the thirteen items used in the analysis (plus one "overall relatedness" criterion). The second column gives the size of the sample, the third, the average relatedness score for each criterion and the fourth, the standard deviation. Significance is given in the two last columns.

Hypothesis # 1 states that Chinese and foreign partners exhibit unrelated morphological profiles. Empirical results for this hypothesis are disappointing. The departures from the average (3.0) are very low with weak significance. There is only a .9 difference (3.5 – 2.6) between the criterion with the lowest rating ("shareholding") and the criterion with the highest score ("Key Success Factors of the sector"). In order to allow comparisons, means differences were tested against the mid-point between these two extremes (3.05). As a consequence, these results have to be interpreted very cautiously.

Hypothesis # 1 tends to find support only for three criteria in the table: "Type of shareholding", "geographical bases" and "size of the company". These received average scores expressing unrelated profiles between the allies. This sounds meaningful. Shareholding is different as foreign companies are mostly privately-owned while Chinese companies are state-owned. Geographical bases are also different: while foreign companies doing business in China are very often global, Chinese companies (even the biggest) usually focus on China. As a corollary of this last point, "size of company" is not at the same level for all the partners.

	n	Average Relatedness	Standard Deviation	t (3.05)	Sig. (bilat.)
Organization of the company	66	2.9091	1.30946	-.8740	.385
Size of the company	67	2.6567	1.17489	-2.740	.008
Shareholding	67	2.5672	1.20885	-3.269	.002
Technology portfolio	66	3.4394	1.11118	2.847	.006
R&D expertise	66	3.0909	1.37815	.2410	.810
Manufacturing capabilities	66	3.2424	1.13762	1.374	.174
Product lines	67	3.3284	1.14664	1.987	.051
Distribution networks	66	3.2879	1.33319	1.450	.152
Geographical bases	67	2.6269	1.32386	-2.616	.011
KSF of the sector	67	3.5224	1.09210	3.541	.001
Competitors	67	3.2388	1.11586	1.385	.171
Suppliers	67	2.8955	1.07498	-1.176	.244
Customers	67	3.4328	1.25799	2.491	.015
OVERALL	60	3.3167	.91117	2.267	.027

Table 4 – Relatedness between the parent companies profiles

The following criteria, "organization of the company", "suppliers" and "R&D expertise" do not depart enough from the average to be significant. On the other hand, the criteria "key success factors", "customers", "product lines", "competitors" appear to be related – which is acceptable in as much as the companies belong to the same business. It must be stressed, once again, that this pattern is weakly significant. Nevertheless, some results were not expected. It is surprising that the criterion for "R&D expertise" does not express un-relatedness between the partner profiles. It is also surprising that "technology portfolio", "distribution networks" and "manufacturing capabilities" were judged as (weakly) related: these results are counterintuitive as most of the writings stress that Chinese products are outmoded and produced in facilities where technology and manufacturing equipment are obsolete (see e.g. Zhang & Goffin, 1999); the results even contradict evidence that will be presented below for hypothesis # 2 and 3. The lack of support for hypothesis # 1 might be that Chinese companies are trying to fill a gap when they look for a foreign partner. After more than twenty years of collaboration with the West, Chinese companies have learnt from their allies. Their morphological profile might not be so far as they used to be from that of their foreign counterpart. This can also be explained more prosaically as a result of the difficulties in translating the concept of relatedness into Chinese, and also because of the bias of Chinese respondents for "medium" figures (whatever the question). For future research, the concept of relatedness, the phrasing and the translation should be improved.

Hypothesis # 2: Resources brought into the joint venture by the partners

The first two columns of table 5 list the twenty-one different types of resources considered in this research (split into six broader categories). The figures (percentages) of the two following columns show where these different resources, pooled in the joint venture, come from. These could be either from the Chinese or from the foreign partner. Cells exhibiting dominant patterns – i.e. with significant differences qualified at $p < .05$ – have been highlighted. The next column gives the standard deviation. The two last give the t-test of mean difference at .5.

		Chinese Parent	Foreign Parent	Std Dev.	t (0.5)	Sign. (bil)
	Financial resources **	.41	.59	.24	-2.783	.00
Physical assets	Land & real estate ***	.93	.07	.22	15.520	.00
	Research equipment **	.36	.64	.38	-2.837	.00
	Production machinery	.48	.52	.34	-.434	.66
	Maintenance tools *	.61	.39	.34	2.584	.01
	Warehouse facilities ***	.87	.13	.25	11.701	.00
Human resources	Workers ***	.97	.03	.13	29.789	.00
	Engineering staff ***	.82	.18	.27	9.471	.00
	Managers ***	.71	.29	.30	5.568	.00
Techno-logies	Process technologies ***	.26	.73	.27	-7.262	.00
	Product technologies ***	.20	.80	.25	-9.538	.00
	Information systems ***	.30	.70	.32	-4.964	.00
Managerial skills	Product development skills ***	.24	.76	.25	-8.249	.00
	Network of local suppliers ***	.72	.28	.33	5.291	.00
	HRM methods & techniques	.44	.56	.32	-1.483	.14
	Manufacturing know-how ***	.25	.75	.25	-7.973	.00
Marketing abilities	Knowledge of the market	.54	.46	.26	1.390	.16
	Marketing expertise	.50	.50	.30	-.081	.93
	Brand image ***	.28	.72	.29	-6.098	.00
	Distribution channels ***	.64	.36	.33	3.350	.00
	Guan Xi with Chinese	.75	.25	.28	7.016	.00

Statistically significant at: * $p < .05$, ** $p < .01$, *** $p < .001$

Table 5 – Resources brought into the joint venture by the partners

These data give strong support to hypothesis # 2. They show that each partner brings very different sets of resources into the joint venture. Out of the twenty-one different types of resources depicted in this table, only four are provided equally by the two partners. These are: production machinery, HRM methods and techniques, knowledge of the market and marketing expertise. This can be understood as, for example, "Hrm methods and techniques" cannot be simply "cut and pasted" from foreign practices and approaches. The imposition of foreign models onto the Chinese context must be questioned. These models need to mingle an understanding of the local culture with some imported expertise.

The other seventeen types of resources are predominantly provided by one of the two partners. It means that each partner specializes in several types of resource. Chinese partners are the main contributors for nine types of resources:

- land and real estate (.93). This situation is a direct consequence of the Chinese law as public or even private companies cannot own land but are merely permitted to use it. This creates a precarious situation for foreign companies which have to rely on their Chinese partner to deal with this issue;

- maintenance tools (.61) and warehouse facilities (.87). This can be explained by a similar argument to the previous one, as well as a legal obligation to buy some tools from local suppliers;

- workers (.97), engineering staff (.82) and managers (.71). Obviously, workers (either blue or white collar) have to be recruited on the spot where business is conducted; this localization is even reinforced when the cost of labour is taken into account – specifically in China which is known for its low-cost labour force. This situation is almost the same for the two other categories of human resources, i.e. engineers and managers. Nevertheless, the lower figures for these two categories (compared to workers) express the fact that there is a significant number of expatriates employed in these positions. This last point gives credence to the assumption made previously regarding the low percentage of expatriates (3.8%) in the joint venture staff;

- the network of local suppliers (.72). This resource is provided by the Chinese partner because it clearly needs some localization – especially under the strong government pressure not only for producing but also for sourcing locally (Osland & Björkman, 1998). The Chinese partner builds on several years of valuable experience with a local network of suppliers;

- distribution channels (.64). It is the local partner which is naturally supposed to have developed a distribution channel on its own territory;

- *guan xi* with Chinese stakeholders (.75). These personal relationships are a core competence brought mostly by the Chinese partner. It is interesting to note that our data show that some foreign companies have already been able to gain access to some *guan xi* with the help of a Chinese agent (who builds liaisons on their behalf) or even to develop their own *guan xi*, i.e. to find their own way through the bureaucracy at local, provincial or central levels.

Foreign partners are the dominant provider for eight types of resources:

- financial resources (.59). Data show that each partner contributes to financial resources. However, the foreign partner is usually the main contributor. This cash probably covers the needs for the first phases of the business, i.e. mainly the launching phase where investment needs are huge;
- research equipment (.64). It should be understood that, in relation with the technologies transferred, the equipment used for conducting research (and development) is provided by foreign suppliers. The foreign partner in the joint venture acts as the one who knows exactly what research equipment should be purchased and where the right suppliers are located;
- process technologies (.73) and product technologies (.80). These resources are considered as the core contribution of the foreign partner. Chinese companies usually pay strong attention to gaining access to new and innovative technology in order to fill the technological gap between China and the West. This point has become the core issue of negotiations conducted before setting up a joint venture;
- information systems (.70). A similar explanation to the previous one prevails for this asset;
- product development skills (.76). Foreign companies are known to master state of the art product development skills – they are asked to duplicate this knowledge in the joint venture;
- manufacturing know-how (.75). A similar argument to the one just given prevails for manufacturing know-how;
- brand image (.72). Brands with global recognition are a key asset whatever the market – consumer or professional. This asset is clearly essential in businesses where technologies are stabilized such as the production of beer; in such a case, product image is the key asset. Because Chinese brands are not as well known as foreign brands, it is understandable that the joint venture uses the latter.

To summarize, Sino-foreign joint ventures clearly exhibit the resources features of an **exogamic partnership**: each partner brings an idiosyncratic set of resources to the joint venture. The Chinese partner tends to bring most of the physical assets, human resources and local connexions; most of these resources are locally rooted or due to country specific knowledge. The foreign partner is the main contributor for financial resources, technological resources (hard and soft), managerial abilities and brand image – these can be more easily transferred from one place to another. These results are consistent with the results of Child & Yan (1999) which show that foreign partners tend to exert dominant control over the Chinese partner for issues like technological innovation, production planning and quality control. Other resources such as production machinery, HRM methods and techniques, as well as marketing expertise, are provided equally by the two partners. Legal obligations might be one of the explanations for this, for example, the obligation to purchase part of the essential operating machinery from local suppliers.

Hypothesis # 3: Learning objectives of each partner

Table 6 shows the empirical results for hypothesis # 3. For each of the 15 types of objectives listed in this study, the next two columns give the average score for the Chinese partner and for the foreign partner. The higher is the score the more important the objective for the partner. These data show three types of pattern.

	Chinese Parent	Foreign Parent	Std. dev.	t (0.5)	Sign. (bil.)
Answer to local or central government pressures	.58	.42	.47	1.322	.192
Build relationships with local suppliers *	.38	.62	.44	-2.128	.038
Find distribution channels outside China	.62	.38	.45	1.989	.051
Gain access to distribution channels in China *	.27	.73	.75	-2.516	.014
Gain access to manufacturing know how ***	.86	.14	.33	8.614	.000
Gain access to the knowledge of the market	.48	.52	.41	-.466	.643
Gain access to labour market ***	.19	.81	.39	-6.100	.000
Gain access to foreign suppliers ***	.77	.23	.41	4.980	.000
Gain access to product technologies ***	.87	.13	.32	9.155	.000
Gain access to production process technologies ***	.90	.10	.27	11.346	.000
Gain access to new product models ***	.83	.17	.34	7.528	.000
Learn about local context ***	.12	.88	.30	-9.882	.000
Learn from the partner ***	.70	.30	.29	5.383	.000
Learn HRM methods and techniques ***	.78	.22	.31	7.071	.000
Learn to manage Chinese workforce ***	.18	.82	.34	-6.848	.000

Statistically significant at: * $p< .05$, ** $p< .01$, *** $p < .001$

Table 6 – Learning objectives of each partner

Five items clearly relate to objectives predominantly pursued by foreign partners: they want to learn about the local context, they want to learn how to manage the Chinese workforce, they want to gain access to the labour market, they want to gain access to distribution channels in China, and they want to build relationships with local suppliers. It is striking that all these assets are precisely those resources pooled into the joint venture by the Chinese partner. Similarly, when working inside a joint venture, managers from foreign companies try to appropriate knowledge about the Chinese environment and this is embodied in the staff of the Chinese partner.

On the other hand, eight items clearly relate to objectives that are predominantly pursued by Chinese partners. They want to gain access to production process technologies, to product technologies, to manufacturing know-how and to new product models; this is not a surprise as these points are known to be weaknesses in Chinese companies. Chinese partners also want to learn HRM methods and techniques. They are interested in gaining access to foreign suppliers. They are looking for distribution networks outside China; the joint venture is an opportunity for gaining access to the foreigner's distribution network abroad. Once again, all these assets are exactly those brought into joint ventures by foreign partners.

Two items fall into an intermediate position: they show objectives that are pursued by the two partners. Both are simultaneously interested in getting a better understanding of the market; the Chinese partner is probably able to contribute to the joint venture an already existing acquaintance with Chinese customers, but at the same time he will probably be benefiting from market research techniques brought in by the foreign partner. Both Chinese and foreign companies have to answer to local or central government pressures. This is because the same constraints are imposed to both partners at the same time.

Local context, *guan xi*, access to distribution networks, relationships with suppliers, product development skills, manufacturing know-how, etc. typically fall into the class of knowledge previously mentioned. This type of knowledge represents, at least partially, some tacit understanding which is unarticulated and almost impossible to formalize. The joint venture is used here as the appropriate channel for each partner to acquire this knowledge in the context of day to day activities and intimate, shoulder to shoulder contacts.

The results of this research give strong credence to hypothesis # 3. The Chinese and foreign partners have significantly different priorities. They establish cooperation in order to learn from each other: each one is trying to appropriate the resources, assets and competencies which the other pools into the joint venture. One straightforward difficulty raised by this point is that the two partners judge the success of the joint venture from vastly different points of reference. Since the partners do not have the same objectives (they want to learn different things), their criteria for evaluating the success of the joint venture will probably not be identical. This is a possible explanation of the dissatisfaction with exogamic joint ventures.

Nevertheless, the very process of knowledge acquisition is not without impact on the stability of the joint venture. The learning by one partner of knowledge brought by the other reduces the dependence of the learner, and consequently, the bargaining power of the "teacher" ally (Inkpen & Beamish, 1997). The cement of the alliance, which is the mutual dependence between partners, then tends to crumble. As soon as the foreigner acquires a good comprehension of the public actors, local market conditions, supplier networks, cultural traditions, standards, statutory values and other environmental characteristics through intimate contacts with the local partner, its dependence on the Chinese partner is reduced. This in turn reduces the foreign partner's motivation to co-operate. It is reasonable to suppose that the foreign partner may even be tempted to operate autonomously. Such situations provide an explanation of the growth in wholly foreign-owned enterprises (Deng, 2001). Similarly if the local partner succeeds in appropriating the technologies and managerial abilities brought by the foreigner, it will be tempted to duplicate those outside the alliance and to forsake the joint subsidiary.

The issue is thus for each of the allies to show itself as efficient as possible in its knowledge management process. A key element is the absorption capacity of each ally. This is a function of the level of education and the permeability of the people in place, of the technological level of development, i.e. of the already existing knowledge bases, the resources available to the firm (capital, infrastructures, equipment, etc.) and of the systems of management, supports and incentives that were set up previously (Zhao *et al.*, 1997). The existence of a differential in the respective absorption capacities of the allies induces different learning rhythms (Kumar & Nti, 1998). These variations explain, to a great extent, the interactions between partners in the alliance and the trajectory it follows (stable, unstable, unilaterally disputed relation, etc).

This last point testifies to the hybrid character of alliances: they combine, at the same time, both co-operative and competitive dimensions. There is thus a true competition within the alliance as each ally strives to accelerate his own training while slowing down that of the partner. In the last analysis, this can be seen as a race for the speed of learning.

Hypothesis # 4: Benefits gained through the cooperation

A simple question asking whether allies were pursuing quantitative or qualitative complementarities in their joint venture gave clear results: fifty-six (out of sixty-seven) said they were targeting qualitative complementarities, while only five were looking for quantitative complementarities (and six were looking for both at once). These crude results seem to support hypothesis # 4. But, the picture is not so conclusive when we look deeper. Table 7 gives the basic statistics for hypothesis # 4. The different lines of the table report the eleven types of benefits supposed to be gained through cooperation. For each of these benefits, the table shows the sample size, the average and the standard deviation. Two types of benefits are covered by the table: quantitative and qualitative criteria. Qualitative benefits are highlighted.

#	Benefits gained through the cooperation	**Sample size**	**Average**	**Standard deviation**
1	Reach an optimal scale	66	3.77	1.27
2	Achieve scale economies	67	3.73	1.34
3	Gain symbiotic effects	67	3.67	1.17
4	Achieve scope economies	67	3.58	1.32
5	Reduce buyer transaction costs	67	3.23	1.27
6	Share the risks associated to the joint venture	67	3.17	1.27
7	Share the financial burden of the investment	67	3.04	1.15
8	Combine different types of knowledge	66	3.00	1.16
9	Increase negotiation power vis-à-vis suppliers	67	2.94	1.25
10	Reach a critical mass	66	2.92	1.29
11	Combine dissymmetrical assets	67	2.84	1.31

Table 7 – Benefits gained through the cooperation

I hypothesized above that Sino-foreign joint ventures are established to produce qualitative, rather than quantitative, complementarities. Unfortunately, this is not the pattern exhibited by these data. Mostly quantitative benefits were found at the top of the list: "reach an optimal scale" (3.77), "achieve scale economies" (3.73), "achieve scope economies" (3.58), "share the risks associated to the joint venture" (3.17) and "share the financial burden of the investment" (3.04). The first criterion reporting on qualitative benefits can be found at rank number # 3: "gain symbiotic effects" (3.67), at rank number # 5 "reduce transaction costs" (3.23) and # 8 "combine different types of knowledge" (3.00). Finally, the last criterion at the bottom of the list with the lowest score, "combine dissymmetrical assets" (2.84), is also a qualitative criterion. As a matter of fact, this table is dominated by quantitative rather than qualitative criteria: the average rank of quantitative benefits is 5.57 (/11) while the average rank for qualitative benefits is 6.75 (/11). In a nutshell, the average score for quantitative complementarities was 3.3 versus 3.18 for qualitative complementarities.

These results are astonishing. They contradict our hypothesis # 4 and also the results presented immediately before in answer to a crude and straightforward question which showed that 84% of the joint ventures were established to gain qualitative effects. Once again, as with hypothesis # 1, questions must be raised regarding the translation of the questionnaire and the construct used to measure this point. Two explanations may be suggested.

First, benefits such as "reaching an optimal scale", "achieving scale economies" or "achieving scope economies" are important issues in a market as big as that of China – especially for the Chinese partner which is usually smaller than the foreign partner. Because these issues are important for Chinese companies and because, in almost every case (56/67), the respondents to this research were Chinese, these points were strongly emphasized. Rankings might have been different if respondents had been mostly foreigners.

Second explanation lies in a specific facet of the Chinese mentality called "moderantism" characterized by "Zhong Yong" (Zhong: middle and Yong: modest). Chinese people do not like to put the emphasis on extremes. As such, on a five subjective point scale, lower ratings (perceived as weakness) as well as high ratings are not appreciated and not welcome. There is a cultural tendency to fall in the middle in order not to create any discrepancies or in any way "rock the boat".

CONCLUSION

This research has demonstrated that Sino-foreign joint ventures are exogamic partnerships. This study reinforces the point that the aim of each partner is to gain access to the knowledge of its counterpart. As soon as one partner has this access, he starts his learning process. As soon as he is able to complete this process, and then, as soon as he is able to duplicate this knowledge outside the joint venture, there is a good chance that the joint venture will end. This explains why Sino-foreign joint ventures are unstable forms of organization. This is especially true if knowledge is a key asset in the joint venture. On the contrary, if tangible assets that cannot be easily duplicated (such as machinery or equipment) are at the core of the deal, the structure will last longer.

Since the beginning of the eighties, foreign companies wanting to do business in China have been forced to establish joint ventures with local partners. However, the last twenty years have shown quick and in-depth changes in China. The country is still in a period of adjustments and transition. Private entrepreneurship continues to develop within service activities as well as in other industries. The most experienced foreign companies have already learnt about the local context. Chinese companies have also learnt from their counterparts; in the future they may create a hybrid model, combining deep Chinese values with Western approaches. Young and well educated managers are coming onto the market. Government is working at solving issues such as Intellectual Property Rights (IPR) and corruption, etc. All these changes are opening the door to wholly-owned structures.

This means that joint ventures are now becoming a true choice. Foreign companies which will establish a joint venture with a local partner in the future will do it as a result of a choice between several options. One of the criteria for making this decision has been explored by the study: partnering has some value as soon as it demonstrates the possibility of access to valuable knowledge for foreign companies. This especially means locally rooted knowledge. This point also has implications for Chinese companies. They will have to pay increasing attention to the value of the resources they bring into the joint venture if they want to be attractive partners. Finding the appropriate partner will be even more critical for them.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
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6

MANAGING TECHNOLOGY AND KNOWLEDGE ACROSS ORGANISATIONAL INTERFACES

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INTRODUCTION

A major challenge in the rapid acquisition and effective deployment of technology for business benefit is the management of technology across organisational interfaces. Symptoms of this problem include well-documented failures of technology transfer, mergers and acquisitions and in the introduction of new products, all of which involve multiple interfaces. These interfaces or boundaries may be within the firm, for example between business units or functions such as R&D, engineering, production and marketing, or between business processes or other organisational elements. Equally, the organisational boundaries may be between firms as in the case of mergers and acquisitions, joint ventures and subcontracting. It is accepted that such interfaces cannot all be removed and thus need to be managed creatively. The focus of this exploratory research is therefore on establishing whether it is possible to identify and characterise the interfaces of the firm where key problems often occur in activities such as technology insertion, new product development, systems integration, strategy and planning. The outputs of this early work will be used to draw preliminary implications for improved management and the scope of further research.

LITERATURE REVIEW

Management context

The effectiveness, productivity, efficiency or excellence of organisations continues to be concern to practitioners, consultants and researchers. "It has served as a unifying theme for over a century of research on the management and design of organisations, yet the empirical research has not yet contributed to the development of a universal theory of organisational effectiveness", according to Lewin and Minton in 1986 and is still true today. There is, however, agreement on some of the barriers to improved effectiveness. These include the internal and external interfaces of the organisation which can corrupt and impede the flow of knowledge and technology (e.g. Allen, 1977; Ouijan and Carne, 1987). Taking a systems perspective, a boundary can be seen as a filter, or set of social norms, which selects both the kind and rate of flow of inputs and outputs to and from a set of components interacting with each other and making up the system (Berrien, 1983). The increasing unpredictability of events and fluidity of boundaries in terms of work roles, works groups, organisations and even industries (Ashkenas *et al.,* 1995) can contribute to a lack of understanding and commitment on the part of personnel. This exacerbates situations such as the structural problem of 'managing part-whole relationships' in the process of innovation, where individuals lose sight of the whole innovation effort (Van der Ven, 1986).

Managing the flow of technology was raised over twenty years ago as a key issue (Allen, 1977) in terms of the importance of proximity for effective communication between R&D personnel. Since then, the internal organisational interfaces between business units, multiple sites and functions such as R&D, engineering, production and marketing have been extensively researched and it is interesting to consider the context of these studies. The main bodies of literature tend to address these 'traditional' interfaces one at a time in key areas of technology management such as integrated strategy development, technology transfer, innovation and R&D management. These are considered briefly below.

Integrated strategy development links technology and other inputs into business planning. There is a need to manage firm competencies across business units rather than being restricted to one SBU (Prahalad and Hamel, 1990) and running the risk that the overall technology and skill portfolio becomes 'invisible' (Coombs, 1995). A contrasting approach focuses on creating a dialogue between commercial and technological functions for effective strategy formulation (Matthews, 1992; Chester, 1994; Cooper, 1993). In this area Burgelman and Sayles (1986) identified several factors that affect the interface between corporate research and business research professionals, including working environment and operating assumptions.

Technology transfer is a dynamic process and includes the consideration of 'givers' and 'receivers' on either side of an interface and the incentives that motivate each group. Examples include the study of 'mobility' of manufacturing expertise between sites (Steele *et al.,* 1996) and identifying factors which influence transfer success (Ouijan and Carne, 1987). Work focusing on transfers between functions examine the effectiveness of moving people (Thurlings, 1996) and methods of neutralising barriers by matching them with specific promoters (Souder and Padmanabhan, 1989).

Innovation (Twiss, 1992; Betz, 1998; Burgelman and Sayles, 1986), new product development and R&D management (Roussel *et al.,* 1991, Granstrand and Solander, 1994) literature covers considerations such as integration, communication and, increasingly, the importance of knowledge (e.g. Pavitt, 1998) in spanning business unit, site and functional boundaries.

In addition to these established areas there is increasing interest in 'new' organizational forms. These include process-based management (Cheese and Whelan, 1996), networks (Shi and Gregory, 1998; Tidd, 1997) knowledge-based structures (Gibson and Niwa, 1991; Senker, 1995; Szulankski, 1996), collaborative new product development (Fraser *et al.,* 2001) and small, growing enterprises (Garnsey, 1998). The role of formal and informal knowledge management roles (e.g. teams, senior positions and 'gatekeepers') and how the flow of knowledge, including technological knowledge, is controlled and facilitated are becoming even more important.

This suggests that there is a need to build on existing research by taking a fresh view of organisational interfaces in the technology management and knowledge-based context. In particular, it is proposed that a number of types of interfaces exist within and impinge upon even simple, technologically related activities. Due to changing organisational structures and ways of working, these interfaces are likely to be more complex and diffuse than previously found. The relevance to manufacturing companies suggests that the outcomes of the work should be biased towards practical application.

The influence of the organisational behaviour perspective

The field of organisational behaviour has been defined as the study of human behaviour in organisations. From this perspective, Winner (1985) identifies three broad but distinct uses of the term technology:

- apparatus (physical device)

- technique (human skill)
- organisation (social arrangement)

Two key bodies of literature are those of organisational change and socio-technical systems. Organisational change processes can be expressed in terms of boundaries and relationships, using the language of open systems concepts, while socio-technical systems are one strand of systems theory (Alderfer, 1976). The open system engages its external environment through the exchange of matter, energy and information. In the case of discharges, this includes waste and product achievement. The socio-technical systems view considers inputs, throughputs and output processes as being sustained by both men and technology (Rosenbrock, 1983). The smallest unit of a socio-technical system is taken to be an 'operation' that produces an observable modification of some aspect of the system.

System change is a complex affair involving internal and external boundaries, internal and external relationships (Alderfer, 1976). It has been proposed that the primary source of change is external to a system (e.g. Katz and Kahn, 1966). Arnold *et al.* (1998) describe two extreme approaches to organisational change: 'stable/turbulent environment' and the 'planned/emergent'. Burns and Stalker (1961), in their research into the management of innovation, identified firms that were able (organic) and unable (mechanistic) to respond to changes in their environment and these correspond quite closely to Alderfer's (1976) distinction between internally open and internally closed organisations. Lewin's equilibrium (1951) of forces for and against change include a set of organisational restraining factors such as strength of culture, rigidity of structure, sunk costs, lack of resources, contractual agreements, strongly held beliefs and recipes for evaluating corporate activities.

Further analysis of boundaries

New knowledge in product development can be considered both a barrier to, and a source of, innovation, as the way specialist knowledge is necessarily structured within functions can lead to difficulties, or knowledge boundaries, when working across functions (Carlile, 2002). Boundary objects can be used to make boundary issues tangible (Carlile, 2002), where boundary objects can be artefacts, documents and vocabulary that help different communities build a shared understanding. Organisational life is about fulfilling roles as boss, subordinate, team leader, team member, mentor, colleague, etc. Role conflicts can exist within individual employees, such as functional role and project role and role transitions can be seen as boundary crossing activities (Ashforth *et al.*, 2000). Segmentation of roles or integration of roles are possible approaches for stimulating cross boundary working but have implications for individuals (Ashforth *et al.,* 2000). In addition individuals themselves can be 'labelled' in terms of social categories (e.g. job title) which may result in altered interpersonal interactions etc (Ashforth and Humphrey, 1995) giving rise to additional boundaries. Problems such as environmental issues transcend organisational boundaries and so prompt collaborative or network working (Clarke and Roome, 1995). Communication as a cross boundary process is raised by many authors, for example in the context of work, structure and the use of communication technologies (Hinds and Kiesler, 1995), personal boundary spanning (Conway, 1995), and networks and green innovation (Steward and Conway 1998).

METHOD

The objective of this exploratory research is to carry out a preliminary investigation of the organisational interfaces involved in managing technology and knowledge within the firm. The motivation for this work comes from previous research in the area of technology management and technology planning, including technology roadmapping, which highlighted the significance of organisational boundaries in the reality of the business context and companies' efforts to address current business issues.

The investigation is based on the preliminary examination of three research questions which may form the basis of a more extensive research programme:

- How can organisational interfaces be identified and characterised?
- What are the key interfaces in managing technology within the firm?
- What are the implications for managing technology more effectively?

The type of investigation is literature review and case study. So far two short scoping interviews have been carried out. The objective of these interviews was to establish whether it is possible to analyse organisational interfaces within companies, whether interfaces are seen as an important issue by industry and whether interface issues underpin relevant industrial problems. A semi-structured interview guide was prepared, based on the following points:

- Explanation of research interest and exploratory nature of investigation
- What are the key problems in managing your technology?
- What organisational interfaces are involved?
- What is being transferred/exchanged?

- Does technology roadmapping help communication across interfaces with business impact?

RESULTS

Scoping interview 1

The first was within an R&D laboratory of a global consumer electronics company. The key issues that emerged included:

- How firm organises internally defines its internal boundaries, but this is not always done in such as way as to optimise boundaries
- Importance of personal networks and stakeholder groups in communicating and filtering research ideas
- The rigidities built into product architectures can restrict cross-boundary working to address customer needs (platforms / specialisations)
- The difficulties of getting people to move with their technology in a global company
- Internal market distorts the dynamics of technology transfer due to cash flow considerations
- The advantage of having a physical boundary eg an application project is easier to grasp than a competence group

Scoping interview 2

The second interview was within an Engineering group of a Tier 1 automotive supplier. The key issues that emerged included:

- Systems focus and cost reduction initiatives mean that internal interfaces are the most important
- Relying more on suppliers for technology, so partnership and co-development is becoming more important
- Key interface difficulty is knowing when to say no to opportunities
- Resident engineers from customers and suppliers given office space
- Key challenge is lead free electronics in automotive – cross interface working on this

- Technology roadmapping is seen by the interviewee as a key tool to disseminate information and support integration of effort.

Common issues

There are common issues across both organisations, for example:
- Both had been recently reorganised (within the last year) to improve operation: one into research groups reflecting closeness to market, the other to a more product/function matrix structure.
- Both have processes that manage the key TM interfaces: the research process and the NPD process.
- Both see packaging of information as a key challenge: either to sell concepts to customers or to inform, disseminate, link and challenge internal people.
- Both have experience of encouraging co-operative working within groups: either in terms of rules of engagement for teleconferencing with colleagues abroad or grouping like thinking engineers within open plan offices
- Roadmapping was a familiar concept in both companies. In consumer electronics roadmapping was seen very much in terms of product roadmaps. In automotive, they were seen as a potential tools for communication across internal and external boundaries.

DISCUSSION

The literature suggested that there would be interface difficulties between commercial and technical groups. The people interviewed were technical however they had considerable interaction with the market, either through providing early prototypes for market place trials or by bidding for business and managing suppliers. It appeared that in these companies, the technical people are highly integrated into commercial activities and play a number of different roles, for example engineering manager, product team member, informal network node and boundary spanner in a key technology area. The literature also suggests several solutions for technology transfer problems, including transfer of people. However the experience of one of the interviewees in practice was that in the majority of cases, this method was not effective due to people's reluctance to leave their established home and work environments. Boundary objects, such as early prototypes in consumer electronics are successful, as are cross business/industry problems, such as the environmental legislation requiring lead free electronics in the automotive industry. The contribution of the interviews to the three research questions are outlined below:

How can organisational interfaces be identified and characterised?

It is difficult to isolate one organisational interface from another in a business. However the clearest identification is through the formal structure of the organisation, as this determines largely who sits where and who works with who, even across geographical boundaries. However informal networks of contacts are also important and these are often reinforced by formal positions. Dependent interfaces are given transparency by defined business processes, for example the research or new product development process. This helps people to make sense of their place in the overall innovation effort and to relate to the organisation's strategy. Preliminary analysis suggests that organisational interfaces can be identified by examining the formal and informal structures within the organisation and their links outside the organisation, and characterised in terms of hierarchical level, specialist knowledge and dependence on other interfaces.

What are the key interfaces in managing technology within the firm?

The responses obtained highlighted business impact, such as 'low cost, high quality design' or 'making potential markets specific', involving outcomes due to many related interface interactions. One key interface highlighted by both companies was the geographical separation of members of engineering or research groups. Another a key interface may be found between different product groups and between different specialist groups. For example, in consumer electronics this is due to the multi-functional products which are now expected by consumers, whereas in Tier 1 automotive suppliers it is due to the increased systems focus. However, the interviews also revealed specific drivers for each company, which suggests that some key organisational interfaces will differ depending on sector. For example in terms of external boundaries, automotive is looking increasingly to suppliers for technology, while consumer electronics is looking to sell new product concepts based on existing technology to consumers.

What are the implications for managing technology more effectively?

A key challenge for both companies was communication, both with future users and within their own organisation. It appears that techniques such as technology roadmapping may have a role in supporting cross-boundary communication.

CONCLUSIONS

Further analysis of literature themes and data from the scoping interviews is required. However it is difficult to draw firm implications from these findings due to the broad field and the limited investigation. Therefore it is planned to use the results of the scoping interviews to structure a more focused interaction with a wider range of companies and people. The preliminary proposal for this increased focus is to look at communication mechanisms across one internal & one external organisational boundary selected from those suggested by the pilot interviews to be key, for example engineering-supplier relations and geographical separation. Example mechanisms would include roadmapping, boundary objects, multi-role individuals and informal networks. It is considered that this focus will help to characterise individual boundaries more clearly and give a better idea of the scope for a possible larger project. Hence further work will involve more interviews followed by an academic / industrial workshop to discuss preliminary results.

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7

INVESTIGATING THE ENABLING MECHANISMS FOR ENSURING QUALITY OF COMMUNICATION IN NEWLY "VIRTUALIZED" PROJECT TEAMS

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INTRODUCTION

Project management has clearly entered the "virtual" arena over the last few years. The radical transformations in industry have brought about new ways of conducting projects; the same is true of the organization and management of production. The ongoing development and increasing availability of information and communication (IC) technologies have opened up a wide array of new possibilities for organizations. Tapping into expertise from various specialized sources and reducing travel costs are among the advantages that these technologies can offer to project teams. From the project manager's perspective, these technologies can provide access to even more information than traditional methods. In this context, it is no longer possible to structure a project management approach without considering the use of IC technologies. Examples illustrating this state of affairs are regularly reported in both professional and academic publications (Burke 1998, Guss 1998, Lipnack and Stamps 1999, Giffin 2002).

However, the successful use of IC technologies is not as smooth as it seems at first glance. In some cases, it represents a real challenge for project managers who are not used to these kinds of tools. In terms of quality of communications, it has been shown that tools such as e-mail, videoconferencing and other electronic meeting devices may result in a decrease in the richness of the information (Adams and Adams 1997, Daft and *al.* 1987, Purdy and *al.* 2000). Even with modern technologies, working on a distributed basis may impede the project manager's ability to "feel" his/her project and to be proactive in dealing with conflicts that may emerge from time to time as the project progresses (Kimball and Eunice 1999). In the traditional, face-to-face way of conducting projects, it seems easier to contain conflicts and to avoid escalation when conflicts do occur (Dube and Pare 2001).

Working in a virtual or distributed team may also impact on team spirit or make it more difficult to establish a solid, unified view of the project (Kimball and Eunice 1999). This can be even worse if team members have never met each other or worked together, if they do not report to the same person or are acting on several projects simultaneously, or if they do not share a common professional, organizational and/or national culture (Perlo and Hills 1998). Finally, some authors have argued that, even with sophisticated IC technologies such as those widely in use nowadays, one cannot completely eliminate the risks associated with information "bulimia," that is, an overdose of information (Back and Moreau 2001).

Considering that communication is viewed as one of the most important success factors in project management (Pinto and Slevin 1998, Pitagorsky 1998), one can view the above factors as major obstacles for successfully conducting virtual projects. In order to avoid their negative effects, organizations and project teams therefore need to consider certain mechanisms. The nature of such mechanisms is a topic that has attracted many researchers in recent years. As it is shown in the following section, the list of mechanisms varies substantially and so does their impact on the quality of communications. A succinct review of those mechanisms leads to three groupings, forming the basis for the empirical investigation that follows.

Overall, the objective is to identify which mechanisms appear the most useful for project managers who have little experience with virtual project management in a context of engineering/innovation-related projects.

RESEARCH BACKGROUND

The importance of communication in project management is well recognized. In a recent book on "radical" project management, Thomsett (2002: 89) encapsulates this idea in his rule no. 15: "[as project managers] you cannot not communicate!" Beyond the catchy wording, Thomsett reiterates the fact that communication can be a two-edged sword. In this context, it is really up to project managers to make sure they communicate effectively (Pinto and Slevin 1998).

In day-to-day duties, communication is the vital link between project managers and stakeholders. It is used for numerous reasons, including sharing information and ideas concerning the project's objectives, assigning responsibilities, keeping people informed about the project, making decisions, managing conflicts, etc. (Pitagorsky 1998). Good communications require the editing, collection, diffusion, storing and processing of project-related information in a precise, timely and adapted manner (PMI 2000). When done properly, communication can help reduce unproductive activities, duplicate information and errors (Clarke 1999). Moreover, it has been shown that good communication stimulates teamwork and improves motivation in a team (Lehnisch 1985).

With an increasing number of projects being undertaken on a distributed basis, communication has become even more important for managing projects successfully. Practitioners who deal with these projects recognize that relying on electronic means to communicate may be challenging (Adams and Adams 1997). As face-to-face meetings are less frequent, teams are most likely to lose some of the richness of communication and therefore to face a higher risk of conflicts (Dube and Pare 2001, Lipnack and Stamps 1999).

In order to support project managers in their duties, certain communication-related mechanisms can be put in place within the organization:

A first category focuses on tools and systems that must exist if people are to share information and communicate. In a context of virtuality, one often tends to see information systems as being at the center of the communication issue (Amami and Beghini 2000, Back and Moreau 2001). For example, recent studies have shown that information sharing is a fundamental aspect of engineering work since activities such as design and marketing of products are inherently collaborative (Hertzum 2002). Based on previous studies, this author reports that engineers involved in development projects spend between 40% and 60% of their time communicating with colleagues or partners. Furthermore, the current interest in knowledge management and the systems that support it is also indicative of the importance people attribute to information technologies when thinking about teamwork, information and communication (Grover and Davenport 2001, Satyadas 2001). In the context of projects, managers and team leaders therefore need to rely on tools and systems that allow them to share, save, and consult relevant information anywhere and at any time (Mead 1997). According to Kimball and Eunice (1999), tools such as an intranet increase the efficiency of a virtual team by allowing people to retain a global vision of the project, enabling them to "keep in touch" with the sponsoring organization, and even facilitating informal communications. Other examples show how beneficial central servers can be for a company which has multiple teams spread out around the world (Mead 1997).

A second category of mechanisms focuses on the process whereby project teams choose to exchange information and communicate. In other words, beyond the tools and systems available, how project team members actually use these tools needs to be thought out (Adams and Adams 1997). In practical terms, this refers to the establishment of rules, protocols and/or processes that provide a framework for the people involved in a project (Pitagorsky 1998, Laudon and Laudon 2001). The notion of rules is particularly important in a context where a project is not only geographically dispersed but is also characterized by diversity of national and/or organizational cultures.

A third category of mechanisms can be associated with the need "to make the thing work," that is, to ensure an adequate level of participation and buy-in from the various stakeholders involved in the project. This category represents the human side of communication management whereby team members, and particularly team leaders, must create an atmosphere that fosters communication. For example, Perlo and Hills (1998) suggest that the role of "coach" is particularly important for project managers in charge of virtual teams. This person needs to know how to stimulate people and to overcome the obstacles often associated with physical, technological or cultural distance. Developing abilities as a good listener and good communicator (oral/written) seems to be particularly important in virtual teams (Baker 1997). Team leaders are also responsible for building trust among team members and communication is an important tool for that purpose. As argued by Handy (1995), managing projects at a distance depends on trust and so project managers must stimulate exchanges within the team. Lipnack and Stamps (1999) have also shown how informal conversations and other non-work-related discussions represent important steps towards building trust, which, in turn, contributes to more effective working relationships.

This overview of communication-supporting mechanisms shows how diverse and intermingled they are. For virtual project management to be effective, leaders need to pay attention to all three categories simultaneously. Despite the studies cited above, several areas of virtual project management and communication still remain unexplored or have been studied under conditions that may seem debatable. For example, the fact that many studies use samples of students as respondents could be seen as a limitation. It was to alleviate some of these problems and focus on certain types of projects that this research was undertaken.

In this context, we propose to study communications within virtual project management from two main perspectives. The first objective is to study real technological projects from the perspective of project managers. The focus is firmly on certain high-tech industries where projects always involve a degree of uncertainty and complexity. Furthermore, it was important to get the data directly from people who have to manage virtual projects on a daily basis.

The second objective was to study communication and virtual project management in the more specific context of people who are having their first experiences with virtuality. Considering the difficulties associated with "getting virtual," the aim was to identify the mechanisms that project managers prefer in the earliest stages of project virtualization.

DESCRIPTION OF RESEARCH METHODOLOGY

In view of the objectives of the research, it was considered that a direct investigation with practitioners was the best way to obtain rich, contextual information regarding quality of communications in virtual projects.

The data used for this research was collected through a series of semi-structured interviews with 45 professional project managers, mostly engineers, who had managed a project in virtual mode within a two-year period preceding the interviews. These managers were identified based on the convenient sample method in conjunction with snowball sampling, which consists in collecting additional potential respondents through recommendations from the first respondents. The final sample comprised 32 men and 13 women active in various fields including aerospace and aeronautics, telecommunications, engineering services, information systems and transportation. These fields were targeted as they correspond to the objective of studying technological and/or innovative projects with a certain degree of complexity. This choice of industries was also facilitated by the fact that Montreal is the location of many world-renowned firms in these fields. All the interviews were conducted by two people and lasted

60 minutes on average. Interviews were deliberately not recorded in order to establish a relation of trust with the interviewees. Once the interviews had been conducted, the two interviewers' transcripts were compared and combined in order to generate one final report for each interview. Data was then codified using a coding system that reflects the concepts under study.

The majority of projects under study were managed by project managers who were new at dealing with a virtual context. Most, however, were considered to be "successes" by interviewees. The projects' value ranged from CDN $5 million to CDN $300 million and their planned duration varied from few months to three years. The virtual teams in the study included between 20 and 100 people; core teams comprised an average of five people.

Several reasons were given to explain why the virtual mode was the preferred option for managing those projects. These reasons are no different from the various reasons usually invoked in previous research. In some cases, a distributed team was justified by the need to tap into external expertise not locally available. For other projects, it was the financial constraints of the organization that limited regular face-to-face gatherings and so new ways of "meeting" needed to be put in place. Whatever the reasons for organizing a project in virtual mode, members of the virtual teams that were observed showed the typical characteristics of distributed teams where language, organizational and/or national culture, and time zone differ from one member to the next. To add to the challenge, team members were often assigned to several projects at the same time.

REVIEW OF FINDINGS

The close examination of the data collected during the interviews reveals some interesting results. Project managers who are just starting to experiment with virtual project management tend to focus on a very few down-to-earth considerations when they try to evaluate what worked best in their case.

Most of the respondents strongly emphasized the need for face-to-face kick-off meetings. Such meetings have long been identified as a success factor for any project (Guss 1998) but they seem particularly critical in the case of virtual projects. Project managers believe that they can positively influence the quality of communications for the duration of the project by making sure team members meet at the very beginning. Project managers would use this opportunity to present strategic information to all members: project mission, objectives, risks and so on. For team members, this represents a good opportunity to get an overall view of the project and a common understanding of each other's responsibilities. The interviewees declare that, once the project is launched, people will clearly communicate better if such a meeting has taken place.

This view of kick-off meetings is well illustrated by the following comment: *"We used our face-to-face time to organize parties. We wanted to break the ice and be sure to involve all the team members. These meetings were most useful for eliminating, right at the beginning of the project, any preconceptions or suspicion that might have existed towards other members [...] once in virtual, there was literally no distance between people. There was a common understanding and some interest in helping one another [...] these meetings really help people to thaw out! That was a real hit!"*

Once the project has started, face-to-face meetings remain a powerful tool at critical points such as contract negotiation and signature, or resolution of major conflicts. This is particularly true when team members have not previously worked together or have known each other in a different context (Zack 1994).

This research also reveals that if such meetings do not occur at a few, strategic moments throughout the project, there will be an inclination to strengthen traditional controls by means of norms and procedures. This finding can be linked to previous research that shows how, in certain cases such as international projects, there is a tendency towards a task-oriented type of management to compensate for the reduced frequency of interactions and the lower level of trust (Jarvenpaa and Leidner 1999).

A second important finding of the research is the strong emphasis on central servers and centralized databases to facilitate coordination between team members and support the decision-making process. Ensuring the distribution of relevant information to all, including updates on the progress of the work, is certainly a key advantage for virtual teams. Information traceability is another functionality that project managers consider to be very important in dealing with distributed teams, and an information system can provide this. More specifically, respondents emphasize that setting up a properly performing information system is not as simple as it seems. In order for databases to be shared and used effectively, they must be organized in such a way that information of any type (reports, plans, drawings, electronic messages, etc.) can easily be located and read. This is a key role, as highlighted by this manager: *"my role was to ensure that each person received the right document at the right time (...) I was a kind of information hub. I was taking care of the database (...) I would receive documents at any time during the day and would update the database accordingly."* Managing information flows and maintaining the system also appear to be a challenge especially when no specific resource has been assigned to the task. In such cases, it is often the project manager him/herself who has to compensate and assume this responsibility. In fact, his/her central position in the project allows him/her to set the rules, including those related to the distribution, duplication and use of documents. He/She will also make sure that final responsibilities regarding the preparation of formal documents are well understood. This appears to be particularly critical if electronic sharing of documents is not possible

When questioned about communication habits, several managers raised the issue of people's behavior when using electronic messaging systems. While considering them to be an essential tool for virtual teams, respondents observe that the quantity of information being exchanged through electronic mail is gradually becoming a problem. By extension, the quality of communication is also being questioned. The absence of any communication protocol is raised by several managers: *"I wish there were some protocols! When I worked for Company X, we had established some rules for using e-mails. For example, we would use bold or capital letters only for very urgent messages. Here, when I receive a message containing this type of format, I still have the reflex of calling the person to ask him/her what went wrong [...] Another problem is the length of messages; some people tend to write very long messages! In other cases, it is the distribution (the overuse of the CC: function) that is not adapted to the situation."*

So far, these results tend to emphasize the fact that, in the case of virtual projects, the project manager's communication roles become predominant when compared to traditional situations. Some of these roles appear to be specifically related to the newness of virtual project management for the team or the organization. In the cases we observed, it became obvious that project managers had to act as champions in order to convince the top managers to implement certain mechanisms to support the virtual team. This is the case in particular for the organization of occasional face-to-face meetings and for making sure a central server is available to all: *"... the P: drive is the common connection for all to our central server. It contains all the relevant and official documents on the project (...) It works very well. This was my idea (...) It took some efforts to put this in place and convince people of its usefulness!"*

Considering that communication in a virtual mode is not as natural as in normal face-to-face situations, project managers also claimed that they had to emphasize their role as facilitator in order to ensure that each team member performed his/her duties as planned. In the case of teleconferencing, for example, this role is expanded: *"in these meetings, people expect a clear message. The project manager must chair the meeting. He's got the leadership and the priority on discussions. He must remain very attentive to others. It's not easy to identify those members who would like to talk but are nervous or hesitant to do so."*

Overall, project managers need to show particular leadership abilities because of the virtual nature of their projects: *"at a distance, you must be very attentive as leader. It requires a lot of coordination, many reminders, many messages to let them know that I'm waiting for some documents...."* Another manager added: *"Very often, people do not take on their full responsibilities (...) I really need to monitor and control the progress of activities; otherwise they are not done in accordance with our expectations. It is very difficult to delegate and I don't know exactly how I'm going to achieve it."*

BRIEF DISCUSSION AND AVENUES FOR FUTURE RESEARCH

The widespread diffusion of IC technologies has led people to believe that projects could easily be managed and conducted even in the context of distributed or virtual teams. In fact, the professional literature abounds in such cases (e.g. Harter 2001). However, the use of sophisticated technology does not necessarily represent a panacea for ensuring quality communications. In the case of project managers who are new at virtual project management, dealing with communication issues continues to be a challenge. For these managers, face-to-face kick-off meetings are unquestionably important, not only because they provide a rich communication context but also because they create an opportunity to build trust right at the beginning of the project (Handy 1995, Lipnack and Stamps 1999). In situations where no meeting of the sort occurred, it was more due to a lack of financial resources than to a lack of interest, as is often the case (Adams and Adams 1997).

Finding no. 1: In cases where project team members do not rely on previous, mutual experience of virtual management, investing in richer communication means, such as face-to-face meetings at the "front end" of the project can have a positive impact on the communication throughout the project.

With regard to communication tools and systems, project managers rely heavily on centralized systems (database and servers) to support information management. Without an adequate infrastructure allowing the sharing and archiving of project-related documents, no team can claim to be efficiently managing its virtual project. But the presence of such a system is not sufficient as it requires close attention to ensure that information is easily accessible to all the people. Top managers therefore need to invest resources, both financial and human, to make these systems really support management. Exchanging information and communicating in virtual mode also imply that team members have agreed on certain rules such as a communication protocol. As Bartoli

(1990) reports, and as repeated by the respondents in this study, communication can quickly be affected by various "pathologies" if people do not share certain rules. E-mail systems are typically seen as generators of such pathologies (misunderstandings, information overdose, etc.).

Finding no. 2: Information management is critical for managing virtual projects and therefore cannot be left up to individual initiative. Organizations need to make sure that systems, procedures and behaviors are congruent with the project's goals.

Another important point that this research has revealed is how important it is, in the context of virtuality, that certain roles be assigned to key individuals so that interest in communication is sustained throughout the project's lifespan. During the preliminary stages of the project, it may benefit from having a person who champions the setting up of systems and rules, but as the project unfolds, it clearly requires the role of facilitator / moderator / stimulator. Most often, these roles are assumed by project managers themselves even though, in some cases, they are visibly unprepared to do so.

Finding no. 3: Projects that are considered to be virtual require that communication roles be forefronted and that specific individuals be associated with them. These roles do not necessarily rest with project managers.

CONCLUDING REMARKS

This research focused on identifying which mechanisms project managers identify as the most relevant in the context of virtual projects. Building on the current literature, which provides an indication of which success factors should prevail in these cases, this study goes beyond previous work by taking a more holistic view of the problem and by capturing managers' perceptions of their context through interviews. The research reveals some interesting findings and contributes to a deeper understanding of virtual project management.

Overall, it can be concluded that even though virtual projects are becoming routine, there is a lack of understanding of the particular constraints and success factors associated with them. The general underlying thinking is that, no matter what, project members will agree to focus on the aims of the project, with or without "hard" tools and "soft" confidence. Project people are task-oriented and they tend to adjust to financial constraints. But without a more structured response to the specific context of those projects, top management may keep reporting slow learning curves in the way projects are conducted, and project members will continue to feel pressure to produce in a somewhat adversarial context.

Instead of viewing virtuality as a constraint, we hypothesize that virtualizing a project could produce a positive outcome in the sense that project teams have no choice but to pay more attention to the basics of project management such as coordination. Interestingly, the results of this study indicate that means for alleviating obstacles are not exceptionally sophisticated or costly if they are planned and integrated into the firm's project management resources.

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8

COGNITIVE ASSETS: A MODEL TO UNDERSTAND THE ORGANIZATIONAL APPROPRIATION OF COLLECTIVE TACIT KNOWLEDGE

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INTRODUCTION

How can organizations appropriate and manage the collective tacit knowledge embedded in their activities? Many studies have defended that tacit knowledge is an important source for competitive advantage, but theories have not yet addressed in detail how organizations can effectively absorb, manage and put into use the tacit knowledge held by its members.

The literature proposes two main theoretical frameworks for knowledge in organizations: knowledge as a resource and knowledge as a process of knowing. Working in this line, Cook and Brown (1999) proposed that the bridging of knowledge and knowing implies that less focus should be given to the idea of knowledge transfer while more focus should go to knowledge integration processes. Nonaka and Takeuchi (1995) had already observed the importance of the conversions and the mobilizations in creating organizational knowledge but didn't explore the efficiency of these interactions.

This paper proposes a new conceptualization that supports Cook and Brown's view while extending Nonaka and Takeuchi's theory. The model considers a special set of assets in organizations, the cognitive assets, as a key to appropriate the tacit-collective knowledge. Cognitive assets are tangible and intangible organizational assets that constitute sources of the cognition that is necessary for action coordination. These assets allow for the integrity and efficiency of the multiple conversions of individual knowledge into organizational knowledge.

LITERATURE REVIEW

This paper is grounded on the dynamic capabilities view developed within strategic management studies. With intellectual roots in the works of Schumpeter (1934), Penrose (1959) and Nelson and Winter (1982), this view defends that competitive advantage of firms 'lie with its managerial and organizational processes, shaped by its (specific) asset positions, and the paths available to it' (Teece et al., 1997, p.518). Processes are thus key to understand superior performance. These processes comprise learning, coordination, integration, reconfiguration and transformation (Teece et al., 1997). They are social and collective, arising from the interaction of people within a given organization. They are also dynamic and path-dependent, reflecting accumulated behaviors and beliefs based on early corporate successes (Leonard-Barton, 1992).

Within this more general phenomenon of organizational capabilities, we are going to focus on one specific process that has been considered to be at the core of organizational capabilities: generation and appropriation of collective knowledge.

Research on knowledge in organizations came into fashion a little after the resource-based view in strategic management gained momentum. Some researchers started to claim that the most important resource that leads to competitive advantage is knowledge (Grant, 1996b, Spender, 1996). According to their view, firms need superior access to and integration of specialized knowledge to gain capability-based advantages. The fact that not all knowledge is explicit helps to explain why this knowledge-based competitive advantage is not easily replicable: the tacit knowledge (Polanyi, 1966) held by organizational members inhibits imitation by other organizations, given that one of its main characteristics is that it is difficult to articulate and codify. This is especially true for collective tacit knowledge (as discussed by Cook and Brown, 1999), which is the focus of our analysis in this paper. While individual tacit knowledge may be bought in factor markets (through the hiring of members coming from other organizations), the collective tacit knowledge held by groups and teams within organizations is much more difficult to transfer across organizations – unless the whole team and the social setting in which it is embedded is also transferred (Birkinshaw et al., 2002, Granovetter, 1985).

Given that, collective tacit knowledge is the main pillar of knowledge-based competitive advantage.

Knowledge is embedded both in individuals and in the organization (Argote, 1999). Organizations play an important role in the acquisition, processing, storage and application of knowledge. They provide a setting for production, sharing and exchange of knowledge among organizational members. But, more importantly, organizations (or groups inside the organization) also possess some knowledge that goes beyond the knowledge held by any individual in particular. The development of capabilities requires integration of disperse bodies of knowledge (Grant, 1996a), turning them into what is called "organizational knowledge".

How knowledge becomes 'organizational'?

Although most works assume that organizational knowledge exists and that it is more than simply the sum of individual knowledge, the important question of how it becomes "organizational" has not been addressed in much depth. Most authors refer to the work of Nonaka and his co-authors, which remains the sole comprehensive view on organizational knowledge formation.

Nonaka (1994) explains the formation of organizational knowledge through a 'knowledge-creating spiral', where tacit knowledge held by individuals is shared with other members through socialization, then made explicit through externalization, then combined with other explicit knowledge and finally internalized in tacit form – and the process starts over again. In this process, knowledge is created through interactions among individuals with different types and contents of knowledge (Nonaka et al., 2000).

More recent conceptualizations on the process of organizational knowledge creation have stressed the role of knowledge linked to action, in other words the ability to put know-what (knowledge about cause-effect relationships) into practice. Cook and Brown (1999), for example, propose a model for organizational knowledge development based on what they call "the generative dance between organizational knowledge and organizational knowing". Knowing for them is "to interact with and honor the world using knowledge as a tool" (Cook and Brown, 1999, p.389), or the epistemological dimension of action itself. In their view, these two dimensions of knowledge interact continuously to generate organizational knowledge. Orlikowski (2002) defends that knowing is not a static embedded capability or stable disposition of actors, but rather an ongoing social accomplishment, constituted and reconstituted as actors engage the world in practice.

What is still missing

The mechanisms through which knowledge becomes organizational and result in capabilities to perform activities are still unclear. Apart from the process proposed by Nonaka (1994), there is not much else available in the literature, especially on the empirical side. One possible reason is the way the field evolved: by treating knowledge as something people (or groups) possess, until recently it had not accounted for the 'knowing' found in individual and group practice (Cook and Brown, 1999). Knowledge is seen as something we *use* in action but not as something that *is* action. Cook and Brown (1999) defend that these two epistemologies (knowledge and knowing) should be brought together if we want to understand the ability to generate new knowledge and new ways of using knowledge – a central theme to understand capability development. Eisenhardt and Santos (2001) point in the same direction, arguing that a bridging of knowledge and knowing perspectives should focus on knowledge integration processes, in which the development of meaning and the creation of new knowledge occurs though individual interactions and is affected by social contexts.

Another issue still to be explored in knowledge management studies regards the effectiveness of knowledge conversion processes – i.e. which are the enablers that allow for better conversions of individual knowledge into organizational knowledge. Previous studies have shown that there is a certain gap between knowledge and action – groups are somehow not able to transform all their individual knowledge potential into collective knowledge for action (Pfeffer and Sutton, 1999, Senge, 1990).

This paper pushes forward the theory on organizational knowledge formation by introducing the concept of cognitive assets, which bridges knowledge and knowing perspectives to address the effectiveness of knowledge conversion processes within organizations.

Cognitive Assets

Although the idea of "collective cognition" has been contested by researchers on the grounds that "cognition belongs to individuals, not organizations" (Eden and Spender, 1998, p. 193), there is a growing number of studies in management that address this phenomenon at a group or organizational level (see Lant, 2002 for a review). These studies concentrate on cognitive phenomena in and by organizations that impact the organization as a whole. Recent conceptualizations stress that the field must embrace the complexities of the two levels (individual and group), which co-exist though interactive processes (Fiol, 2002, Lant, 2002).

In order to address the issues raised in the last section concerning the drivers for knowledge conversion processes, we propose a concept labeled cognitive assets. Cognitive assets are tangible and intangible organizational assets that constitute sources of the cognition that is necessary for action coordination. These assets allow for the integrity and efficiency of the multiple conversions of individual knowledge into organizational knowledge. They comprise 4 main dimensions: 1) the environmental mechanisms that foster knowledge creation; 2) organizational members´ cognitive capacities; 3) organizational members´ transactional potential (defined as their ability to interact and share knowledge with co-workers); and 4) decision-making methods used by the organization.

Figure 1 brings a representation of the role of cognitive assets. Analogous to the process of individual knowledge creation, cognitive assets represent to organizations what cognition potential is to individuals. The process of new knowledge generation at the individual level can be seen as the systematic and efficient combination of the information available to the individual with her cognitive potential. Similarly, we can model organizational knowledge creation as the systematic and efficient combination of information-based assets with cognitive assets.

Cognition research in organizations has taken two main approaches: one computational and one interpretive. The computational stream examines the process by which managers and organizations process information and make decisions; the interpretive approach investigates how meaning is created around information in a social context (Lant, 2002). Our concept of cognitive assets takes both perspectives into account; individuals´ cognitive capacities and organizational decision-making systems are linked to the computational view, whereas the environment and transactional elements are linked to interpretive efforts. As defended by Lant (2002), putting together these two perspectives will deepen our understanding of organizational cognition. Our objective is not to take sides in this debate; rather, we aim to have a comprehensive model that captures all richness of collective cognitive processes. The next section expands the discussion on the dimensions of cognitive assets.

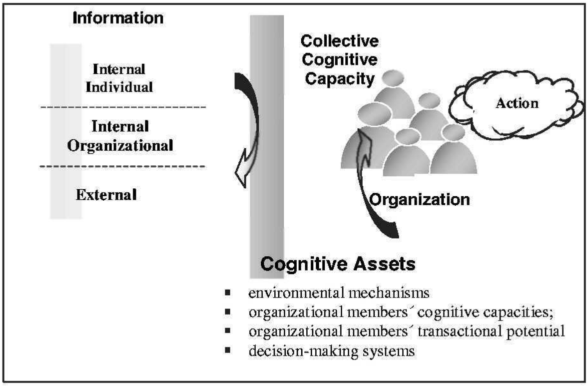

Figure 1 – The role of cognitive assets in organizational knowledge formation

Dimensions of cognitive assets

Environment. Differently from cognitive studies done in psychology, where laboratory experiments are used to address issues of individual cognition, researchers of cognition in management have stressed the role of the environment where decisions and actions are being taken and the interactions of people within this environment. Knowledge is seen as a function of the social and physical system in which it exists (Birkinshaw et al., 2002).

For example, the influential work of Karl Weick has always stressed the fact that sensemaking is a collective interpretive process (Weick, 1979, Weick, 1995, Weick and Bougon, 1986). As proposed by Lant, "cognition is situated within a cultural system, including artifacts and practices" (Lant, 2002, p. 357). Given those characteristics of collective cognition process, the most basic dimension of cognitive assets is the environment where cognition takes place.

The environment provides regulative (rules) and normative (values and norms) dimensions that govern organizational life. It sets the pre-conditions that allow for the transformation of individual knowledge into collective knowledge put into action. Following Orlikowski (2002), five sets of activities are important in the organizational environment: (1) sharing identity; (2) interacting face to face; (3) aligning effort; (4) learning by doing; and (5) supporting participation. Managers can increase the effectiveness of knowledge conversions by stimulating these five sets of activities in the areas under their control.

Individual cognitive capacity. The second important dimension of cognitive assets is the individual cognitive capacity of organizational members, which corresponds to their ability to process information efficiently and effectively to attain goals. That ability contributes to more and better conversions of information into collective knowledge.

Research in cognition has burgeoned in the past 30 years. It is beyond the scope of this paper to bring a comprehensive view on the main findings of this stream of research in psychology; we will present here some findings that pertain to the effectiveness of information processing inside organizations.

Humans have a knowledge structure (or schema), which "represents organized knowledge about a given concept or type of stimulus" (Fiske and Taylor, 1991). This knowledge structure is a mental template that individuals impose on an information environment to give it form and meaning and to enable subsequent action. That way, it has strong influence on the process of transforming information into action.

The two most commonly studied attributes of knowledge structures are differentiation (the number of dimensions within a knowledge structure) and integration (the degree of interconnectedness among the knowledge structure dimensions) (Walsh, 1995). The higher the differentiation and integration, the more effective the knowledge structure is. Little differentiation leads to a narrow vision, which results in ineffective managerial behavior (Bartunek et al., 1983). Differentiation and integration are influenced by personality variables (level of aspiration, job involvement, cognitive complexity) and organizational experience (position in hierarchy, work experience) (Walsh, 1995).

Transactional capacity. Even if the environment is conducive to knowledge sharing and individuals have high cognitive capacity, the ability to generate and put into use collective knowledge will also depend on individuals' ability to connect to each other. Transactional capacity is ability individuals have to absorb, codify and share information and explicit knowledge in order to meet organizational objectives. Transactional capacity will be a function of personal and structural dimensions. For personal characteristics, Eric Berne's transactional analysis (Berne, 1973) in psychology studies three important dimensions: (1) learning; (2) rationality; and (3) emotions.

The structural dimension of transactional capacity is linked to the various networks within the organization. Social networks and the role of social capital have received an increasing attention in sociology studies over the past few years. There are two main approaches: one that follows the work of Coleman (Coleman, 1988), which defends that social capital occurs in networks with closure, where the value of social capital resource is communication among members; another approach, deriving from Granovetter and Burt (Burt, 1992, Granovetter, 1973) defends that social capital occurs in networks without closure where the value of social capital resource is derived from brokering information and exercising control. The seemingly conflicting predictions of these two approaches may be due to the fact that each one has analyzed different environments (Raider and Krackhardt, 2002). But regardless of the closure of social networks, the existence of a network and individuals willing to share information within it (and capture from outside it) is important. Dyer and Nobeoka, for example, defend that a highly interconnected network benefits all members by facilitating knowledge sharing and learning and increasing productivity of members (Dyer and Nobeoka, 2000).

Decision making systems. Organizations use different systems to help their decision-making processes. Operations research, management science and decision science methods can be seen as analytical cognitive processes that help decision-making. These methods serve to increase the efficiency of the knowledge conversion and mobilization processes, increasing managers´ ability to process information and make decisions. That way, they are also important constituents of cognitive assets.

We define these systems rather broadly: any activity that, based on explicit (but not necessarily formalized) models, helps decision-making agents to obtain solutions to their problems given their preferences and the uncertainty of the environment. Together with individuals' cognitive capacities, they define the organization's capacity to process information and make decisions.

Implications

The main objective of this paper is to address the issue of effectiveness of organizational knowledge creation processes. Figure 2 brings a summary of the elements we propose as the main drivers of these processes. The four elements that comprise what we labeled "cognitive assets" have all a positive effect on organizational knowledge creation, because they increase the effectiveness of conversions of individual knowledge into collective tacit knowledge.

Implications for managers regard the management of the four different elements that we discussed above. As we saw, all elements depend not only on personal characteristics but also on organizational features. For example, the five main sets of activities for knowledge creation in the internal environment should be fostered at all levels in the organization; individual cognitive capacities can be augmented by providing individuals with more opportunities for differentiation through more challenging jobs; transactional capacity can be fostered through the informal and formal networks; and better decision systems can be designed and put into practice.

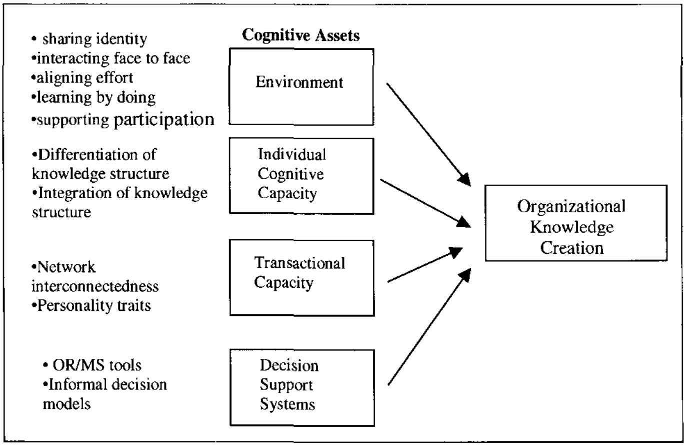

Figure 2 – Main propositions of the model

There are also contributions to the theory on knowledge management. First, we address explicitly the efficiency of knowledge conversion processes, something that has not been explored in much depth by Nonaka and Takeuchi (Nonaka and Takeuchi, 1995). Second, we put together knowledge and knowing dimensions, something that has been identified as one the major avenues for research in the next few years (Eisenhardt and Santos, 2001). Third, we are putting together perspectives from different fields (strategic management, psychology, sociology, operations management), which increases the potential for insight generation and novel findings.

This is a first conceptual step into a better understanding of performance dimensions of organizational knowledge and knowing. There is still a lot to be done in that direction. In other to push the arguments presented here further, empirical studies are needed different areas: (1) testing the construct "cognitive assets" and the four dimensions that we propose here; (2) bringing data-driven thick descriptions of the constituents of cognitive assets; and (3) linking cognitive assets to performance. There is still a long journey ahead, but one that we believe is worth taking.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

9

DOES KNOWLEDGE MEAN SUCCESS? - CAPABILITIES, STRATEGIES AND INTERNATIONAL PERFORMANCE OF SMALL KNOWLEDGE-INTENSIVE FIRMS

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INTRODUCTION

Knowledge, i.e. knowledge-based competition and knowledge-management has become a focal point of interest to management scholars and practitioners. In many recent studies, knowledge is seen as the most important source of competitive advantage and knowledge capabilities or resources are seen to contribute most to performance (Grant 1996, Miller and Shamsie 1996, McEvily and Chakravarthy 2002).

An important aspect of well-known resource-based view of the firm (RBV) concerns the ability of the firm to generate rents from different types of capabilities and

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resources (see e.g. Wernerfelt 1984, Barney 1986, Grant 1991). To emphasize the importance of the dynamic aspects of knowledge creation in the search of sustainable competitive advantage, in many recent studies the RBV has often been called as knowledge-based view (KBV) of the firm (e.g. Grant 1996). Our study follows this principle and explores the relationship between different capabilities and skills and the international performance of small knowledge-intensive technology-based firms.

Growth by internationalization is an important strategic option for small-and medium sized enterprises (SMEs). During the last two decades, there has been a lot of published evidence and research on the internationalization of small knowledge-intensive firms (see e.g. Coviello and McAuley 1999, Zahra *et al.* 2000). Brush and Vanderwerf (1992) notice that prior studies have shown that a combination of different factors increase the possibility of international expansion by new venture firms. These include for example industry factors, institutional factors, and organisational factors (e.g. company characteristics, corporate objectives, and capabilities). There are many different theories and models explaining the internationalization process of the firm (for a review of models and their applicability, and studies in SME context, see e.g. Coviello and McAuley 1999). The RBV has been used in some studies to explain internationalization or the choice of international growth strategy (Andersen and Kheam 1998, Peng 2001) and it can be seen as a useful approach in the search of explanations for the international performance. Knudsen and Madsen (2002) argue that the creation and co-ordination of new knowledge and routines inside of the organisation is the crucial part in developing the important determinants of export (i.e. international) performance. The present study attempts to extend the relevant literature by examining the different possible determinants of international performance in the context of small knowledge-intensive technology-based firms from the knowledge-based perspective. The normative aim of the study is to give empirical evidence, what kind of capabilities can be seen as significant indicators of international performance.

The following four sections present the theoretical background of our study concerning the KBV and international performance. Subsequent sections propose our hypotheses, empirical results and their analysis. In the empirical part of the paper we use structural equation modelling to study different paths between proposed determinants in which both different types of capabilities and strategies are included as a possible source of performance. The last section of the paper includes conclusions and suggestions for further research.

INTERNATIONAL PERFORMANCE

There is a substantial body of empirical research published on export or internationalization success factors, and numerous variables have been identified as determinants of success (see e.g. Aaby and Slater 1989, Leonidou *et al.* 2002). Different determinants with which international (or export) performance has been conceptualised can be integrated into three groups: 1) managerial characteristics, 2) organisational factors, and 3) environmental forces (Leonidou *et al.* 2002). Of these, the first two groups are part of a firm's internal knowledge base. According to the KBV, these firm based capabilities should contribute most to performance.

Traditional performance measures include economic goals (e.g. profitability and sales). Depending on measurement purposes, and sample etc., different non-financial measures have been used (e.g. market-related and product-related measures, and measures such as managers' satisfaction with export performance, as well as fulfilment of export objectives (see e.g. Leonidou *et al.* 2002).

KNOWLEDGE-BASED VIEW OF THE FIRM AND INTERNATIONALIZATION

Knowledge-based view of the firm, while accepting much of the content of the RBV of the firm, emphasizes more the process or path by which the specific capabilities evolve and develop over time. The firms are seen as repositories of knowledge. The proponents of the dynamic capability or knowledge-based tradition, Teece and Pisano (1994: 537) interpret firms as generators of specific dynamic capabilities, which help "in appropriately adapting, integrating and re-configuring internal and external organizational skills, resources and functional competences toward changing environment." Dynamic capabilities are "rooted in high performance routines operating inside the firm, embedded in the firm's processes, and conditioned by its history" (ibid). Eisenhardt and Martin (2000) see dynamic capabilities as "best practises", or tools by which firms can manipulate their resource configurations. Firms, which can create, manage and transfer knowledge that is valuable, rare, and hard to substitute (i.e. asset specific) in an international context are more capable of outperforming their competitors in the long run. Development of knowledge through learning and an ability to change are seen as key components in evolutionary knowledge management (Eisenhardt and Martin 2000).

KNOWLEDGE AND INTERNAL CAPABILITIES AS DETERMINANTS OF PERFORMANCE

Knowledge and expertise in different functional competencies have been found to be positively related to international growth (e.g. Cavusgil and Zou 1994). There are several typologies of the properties of resources or capabilities (see e.g. Grant 1991, Miller and Shamsie 1996, Spanos and Lioukas 2001). Spanos and Lioukas (2001) divide them into organisational, technical and marketing capabilities. Lee *et al.* (2001), in their study of small technology-based firms, use a classification of internal capabilities consisting of entrepreneurial orientation, technological capabilities and financial resources. In this paper we use a classification combining these two latter-mentioned studies, as entrepreneurial orientation can be seen as an important aspect of growth and internationalization (see e.g. Knight 2001). In addition, received financial investments and new technology-based firms' linkages with venture capitalists have been found to be important indicators of performance (see e.g. Lee *et al.* 2001). All these capabilities form the knowledge base of the firm.

Functional Capabilities

Marketing capabilities: Even for technology-based small firms marketing capabilities, for example, ability to learn customer needs and position its product successfully (see e.g. Zahra *et al.* 2000) are often significant determinants of success. Existing knowledge related to the market is seen as an important skill, as in many cases small firms follow focus/niche type strategies with an aim to service chosen market segment needs. For example, Wolff and Pett (2000) argue that customer service and high quality marketing strategies need a much narrower resource base than e.g. brand strategy, and are then more possible for SMEs.

Technical capabilities: Technical capabilities are among the most recognized determinants of success in small knowledge-intensive firms (Zahra 1996). They can be seen as the sum of knowledge and skills which determine the ability of technology-based new ventures to develop and offer different types of products and services.

Organizational capabilities: According to Teece *et al.* (1997) organizational capabilities include e.g. managerial competence related to organizational and managerial processes, knowledge and skills of employees altogether, with an efficient organisational structure. In internationalization, the role of the management team and strategic planning have been highlighted in many studies (e.g. Knight 2001).

Financial capabilities: Smaller firms tend to have fewer financial resources and have more difficulties in obtaining the necessary funds for product development, marketing, exporting and internationalization in general (see e.g. Lee *et al.* 2001, Westhead *et al.* 2001). Firm's ability to obtain financial resources (i.e. connections to different types of investors) and manage these resources may enable the firm to secure new markets and operate successfully in them. Financial capabilities in the SME context have been studied through different types of measures, including e.g. investments made in the firm in a certain time period (Westhead et al. 2001).

Internationalization Capabilities

Learning about internationalization is a cumulative process, in which all the steps or activities at international markets add experimental knowledge to the firm (Johanson and Vahlne 1977). The implications of the learning process of the firm (or management) are that the past contributes to its current knowledge base. As in development of all capabilities, the internationalization skills are path dependent (see e.g. Eriksson et al. 2000). Internationalization capabilities are often measured through the experience of the firm in international operations (e.g. countries served, years of operation, capability to engage itself in international operations), or through management experience and orientation towards international activities (experience in international activities, perceived importance of internationalization, international entrepreneurial orientation) (see examples of different measures, e.g. in Lu and Beamish 2001, Eriksson et al. 2000). Some authors (e.g. Knight 2001) see international entrepreneurial orientation as fundamental corporate posture reflecting firms' overall proactiveness and aggressiveness in its pursuits of international markets. It is associated with managerial vision, innovativeness and proactive risk taking competitive posture (Covin and Slevin 1989). Here we see international entrepreneurial orientation and experience in international operations as an internationalization capability of the firm.

EFFECTS OF STRATEGIC ORIENTATIONS AND COMPETITIVE SITUATION

As firms differ from each other with respect to their resources and capabilities, they are also likely to differ in the actions taken to develop and implement strategies. The performance of the firm or sustainable competitive advantage can be seen to be dependent on the strategic orientation and activities of the firm based on the following a certain orientation/strategy.

It is well accepted that firms compete in their respective product and service markets using a strategy which can be related to the three generic business-level strategies presented by Porter (1980). Yeoh and Jeong (1995) notice that marketing orientation (or strategy) tends to represent the strategic responses of a firm to environmental uncertainty. This notion is applicable to the marketing strategies of SMEs in the international setting. Also technological differentiation (innovation based) strategy is clearly used in the context of technology-based small firms, as product innovations are often the reason for existence of these firms.

It is argued that a well-defined strategy or strategic orientation has an effect on international performance (see analysis e.g. in Leonidou *et al.* 2002). Although there are inconsistent results of links in strategy-performance studies, we follow Spanos and Lioukas (2001) and include composite strategy construct (for marketing and technology based strategies) in our empirical study. This mixed strategy approach is considered appropriate in the competitive environment (see e.g. Spanos and Lioukas 2001). However, it is important to notice that for certain types of firms, e.g. for small ICT-firms in our sample, the traditional low cost strategy may not be viable as there are no economies of scale available yet.

Environmental forces, for example the industry structure the firm operates in can have a significant effect on international operations of knowledge-intensive technology-based small firms (see e.g. Porter 1980, Yeoh and Jeong 1995). Depending on, for example, market turbulence, the amount of competition both at domestic market and abroad, and the relationship between environmental forces and international performance can either be positive or negative. Thus, it is assumed that there is a causal relationship, i.e. a link between the competitive situation and performance, although it is context specific. The strategy and environmental, competitive determinants are included in our model as possible additional determinants of performance.

MODEL DEVELOPMENT AND HYPOTHESES

On the basis of the arguments presented above we propose a model incorporating the different possible explanatory factors of international performance. These include 1) capabilities-based (i.e. firm specific) effects, which according to the logic of KBV, provide the conditions for the sustainability of performance, 2) strategy effects that are a necessary basis for above-the-average performance, and 3) competitive situation/industry effects (i.e. environmental forces).

- H1 - Technological capabilities have an effect on the international performance of small knowledge-intensive technology-based firms.
- H2 - Marketing capabilities have an effect on the international performance of small knowledge-intensive technology-based firms.
- H3 - Organisational capabilities have an effect on the international performance of small knowledge-intensive technology-based firms.
- H4 - Financial (management) capabilities have an effect on the international performance of small knowledge-intensive technology-based firms.
- H5 - Internationalization capabilities (experience and management characteristics) have an effect on the international performance of small knowledge-intensive technology-based firms.
- H6 - Defined strategy of the firm has an effect on the international performance of small knowledge-intensive technology-based firms
- H7 - Competitive situation has an effect on the international performance of small knowledge-intensive technology-based firms.

All the seven hypotheses presented above are combined in a structural model, with international performance as a dependent variable. The model is tested empirically with the sample of knowledge-intensive technology-based SMEs.

DATA COLLECTION

The population of interest in our study was defined as small and medium-sized Finnish firms providing value added services in the information and communication technology (ICT) sector. A sampling frame was devised through intensive search of multiple sources, e.g. the Kompass Finland Database and The Statistical Bureau of Finland database of Finnish companies. Altogether 493 firms were identified and contacted in late 2001. The 386 firms which were found suitable and which agreed to participate during the telephone conversation received an e-mail message containing instructions for answering a web-based questionnaire. The questionnaire was carefully pretested in a number of firms. A reminder message was sent to those who had not returned their answer within two weeks of the initial telephone conversation. 124 firms responded in total, resulting in an effective response rate of 32%, which is considered acceptable for the intended analytical approach. Of these 124 firms, 55 internationally operating ones are the focus of our analysis. Following Armstrong and Overton (1977) the comparison of early and late respondents was conducted to assess nonresponse bias. Here no significant differences were found. Most of the respondents were managing directors or members of the executive team, as it is believed that they have the best overall knowledge concerning the resources and capabilities of their firms. In this we followed the earlier studies related to the KBV/RBV (see e.g. Fahy 2002).

PLS GRAPH TECHNIQUE

The hypothesised causal relations were investigated using Partial Least Squares (PLS) technique, which is a structural equation modelling (SEM) method. Among SEM techniques by far the best known are covariance-based methods as exemplified by the software such as LISREL and AMOS. However, PLS is a complementary approach, and it can be a powerful method of analysis because of minimal demands on measurement scales (i.e. the distinction between interval and ratio type of measures is not necessary), and residual distributions. PLS also enables the use of small sample sizes (Wold 1985). Although PLS can be used for theory confirmation it can also be used for exploratory research, for suggesting where relationships might or might not exist, and as well for suggesting propositions for later testing (Chin 1998). In comparison to the better-known factor-based techniques, PLS avoids two serious problems: 1) inadmissible solutions and 2) factor indeterminacy (Fornell and Bookstein 1982). Another important feature of the PLS approach is that multivariate normality is not required for estimating PLS parameters. The need to consider the underlying distribution of data only becomes an issue when it is necessary to test the statistical significance of parameters (Barclay *et al.* 1995).

The basic distinction between PLS and other causal modelling methodologies rests in their objective. The PLS approach starts off with a different goal, from a covariance-based solution, to help the researcher obtain determinate values of the latent variables (LVs) for productive purposes. Instead of using the model for explaining co-variations of all indicators, PLS tries to maximise the variances of all dependent variables. Because PLS makes no distributional assumption, other than predictor specification in its procedure for estimating parameters, traditional parametric-based techniques for significance testing/evaluation would not be appropriate. In other words, rather than being based on covariance fit, the evaluation of the PLS model should be done by applying prediction-oriented measures that are also nonparametric (Chin 1998).

These include, for example, the R^2 for dependent LVs. Fornell and Larcker's (1981) average variance extracted measure is used to assess productiveness, whereas a re-sampling procedure called jack-knifing is used to examine the stability of the estimate. Taking this into consideration, the results of our model are analysed in the next section below.

ANALYSIS AND RESULTS

The research data have been subjected to PLS as proposed by Fornell and Bookstein (1982). More specifically, PLSGRAPH 3.0 software developed by Chin (2001) was used. Although the measurement and structural parameters (for both the links between measures and constructs, i.e., loadings, and the links between different constructs, i.e. path coefficients) are estimated together, PLS -model is usually analysed and interpreted at two stages: 1) the assessment of the reliability and validity of the measurement model, and 2) the assessment of the structural model (Barclay *et al.* 1995). This two-tier analysis ensures that the researcher has reliable and valid measures of constructs before attempting to draw conclusions about the nature of the construct relationships.

MEASUREMENT MODEL AND CONSTRUCT ANALYSIS

The measurement constructs are formative constructs, consisting of scales formed from the statements mainly adapted from previous studies (e.g. Spanos and Lioukas 2001 for strategy and capabilities, except financial capabilities scale). The reliability of items was assessed, and it provided a basis for the construct formation for the actual modelling.

The "marketing capabilities" construct included two indicators concerning the firm's perceived ability to offer good service for their customers, and to understand the needs of the industry. The construct "technical capabilities" is formed from four indicators, related to the technical expertise, mastering of technology, the ability to develop new technology, and the ability to adapt one's expertise to new technologies. The "organisational capabilities" construct consists of two indicators measuring the management's perceived ability to co-ordinate the firm's different functions and the ability to use its expertise and skills in many different tasks. The "financial skills" construct consists of one indicator based on the firm's perceived investment expertise and skills. The "internationalization capabilities" construct is a second order composite construct consisting of two composite indicators that reflect the firm's international experience (length of international operations, number of target markets) and the management's international entrepreneurial orientation (consisting of seven indicators related to the international mindset and time spent in planning international operations). The construct "strategy" consists of two composite indicators reflecting marketing differentiation and innovation-based technology differentiation strategies. The "competitive situation/industrial forces" construct is also a composite second order construct reflecting global competition (2 indicators) and turbulent market development (3 indicators). The dependent construct, "international performance" consists of three indicators, reflecting the perceived satisfaction to turnover and image objectives set for internationalization.

Before we continue to the evaluation of the model it is important to notice that our study relies on subjective responses. There are both practical and theoretical reasons behind their use. As our empirical sample is based on SMEs, there is often no "objective" information available. There are also theoretical arguments which support the use of subjective data. For example, Lefebvre *et al.* (1997) notice that CEOs' views of the environment may "override factual characteristics of the environment", and in small firms managers' perceptions tend to formulate the strategies. Following this rationale, our use of self-reported measures may be justified.

Consistent with Barclay *et al.* (1995) we then examine *individual item reliability* of the model. Since all the indicators used within this research are formative, we are interested in the significance of weights. In all cases only those indicators with significant weight in the jackknife test have been accepted. The use of jackknifing as opposed to traditional t-test allows the testing of the significance of parameter estimates from data, which are not assumed to be multivariate normal. It is clear from Table 1 that all the measures used in this study are within the acceptable level, therefore all the measures are retained.

STRUCTURAL MODEL EVALUATION

In testing a model using PLS the primary objective is the minimisation of error (or equivalently, maximisation of variance explained) in all dependent (endogenous) constructs. The degree to which any particular PLS model accomplishes this objective can be determined by examining the R^2 values for the dependent constructs, since R^2 obtained from PLS is interpreted in the same manner as R^2 obtained from a multiple regression analysis (Hulland 1999, Barclay *et al.* 1995). The result in this model indicates that 70 percent of the variance utilisation was explained.

Table 1. Reliability of Measures

Dimension/Items	**Weight**	**Adjusted t-stat Jack**
"International performance"		
1. Turnover objective of internationalization	0.48	2.62**
2. Share of foreign sales from total turnover	0.58	6.80***
3. Internationalization and company's image	0.30	1.70*
"Marketing capabilities"		
1. Industry understanding	0.76	2.96**
2. Clients value our good services	1.13	5.57
"Technical capabilities"		
1. Mastering of technology	0.95	2.01*
2. Our company have better technology expertise than our rivals	1.37	4.39***
3. Our company master technology development better than our rivals	1.03	2.33**
4. Our special expertise can be adapted to new technologies	1.01	2.07*
"Organisational capabilities"		
1. Company functions are well co-ordinated	0.85	2.50**
2. Our company's staff are well trained to be utilised in different tasks	1.30	5.63***
"Financial capabilities"		
1. Investment experience	NA	NA
"Internationalization capabilities (experience)"		
1. International experience (firm level) (construct, 2 items)	0.79	4.05***
2. International entrepreneurial orientation (management characteristics) (construct, 7 items)	0.51	2.50**
"Strategy"		

"Strategy"		
1. Marketing differentiation strategy (construct, 2 items)	1.07	3.72**
2. Innovative differentiation strategy (construct, 2 items)	1.25	4.02***
"Competitive situation/industry effects"		
1. Market turbulence (construct, 3 items)	0.825	2.06*
2. Global market (construct, 2 items)	1.11	7.31***

Note: *** sig 0.001 ** sig 0.01 * sig 0.1

The second element in model evaluation is to assess the significance of the path coefficient that has been tested using the jackknife test. Like the reliability test, the results of the jackknife are evaluated with regard to the significance of the *t*-test. The result of this test is illustrated in Table 2. To validate the model further, we also tested the impact of the firm's size (i.e. number of employees) as a control construct of international performance. It was, however, not significant in our sample.

Table 2. Goodness of Fit of the Model

Construct	Path coefficient	Adjusted t-stat Jack (t-value and significance)
International performance	NA	NA
Marketing capabilities	0.19	2.11*
Technical capabilities	0.11	0.59
Organisational capabilities	0.23	2.31*
Financial capabilities	0.08	1.12
Internationalization capabilities	0.54	3.63***
Strategy	0.09	1.36
Competitive situation	0.08	0.69

Note: R^2= 0.70 *** sig< 0.001 ** Sig< 0.01 * Sig< 0.1

From the above Table 2 three of the relationships can be confirmed to be significant (i.e. marketing capabilities, organisational capabilities, and internationalization capabilities). In the light of these results the hypotheses H2, H3 and

H5 have been supported. The other relationships were insignificant in our sample, and thus, the hypotheses related to these were not supported.

DISCUSSION, CONCLUSIONS AND FURTHER RESEARCH

This study explored the knowledge base of firm, in the form of different capabilities, which are seen as determinants of the international performance of the technology-based knowledge-intensive SMEs. In our research three different types of capabilities proved to be significant in relation to international performance, and it can be argued that knowledge contributes to success. Internationalization capabilities, i.e. the combination of the firm-level international experience and management's international entrepreneurial orientation proved to be a significant predictor. This finding is not surprising as a similar notion is supported in most international performance studies. Related to international entrepreneurship vision, for example, Knight (2001) notices that "...international entrepreneurial orientation is a fundamental corporate posture and contributes strongly to the international performance". This view is confirmed in our sample.

The importance of marketing capabilities is proved in our study. As our sample consisted of technology-based firms, which often see technology as their most important asset, it is important to notice that the other types of capabilities contribute to the actual success. It can be argued that technical skills are needed as a basis for existence for technology-based small firms, but actual good international performance stems more from, for example, marketing capabilities, from customer focus, and other marketing related skills. The above is also true for organisational skills, as one of the big challenges for an internationalising firm is to share and disseminate knowledge between different units, across the country and firm boundaries. The insignificant link between technical skills and performance is more understandable from this viewpoint. As to financial capabilities our measures may not have been able to capture all the related aspects.

Related to the strategies and competitive situation, the findings of our study are less than conclusive and they open new avenues for further research. For example, it seems that our strategy constructs do not work in the international SME context or at least not in our sample although Porter's business level strategies are seen to be applicable to small firms (see e.g. Wolff and Pett 2000). Thus, an interesting addition to this study could be to include more detailed internationalization strategies as moderators in the model as has been done in some studies (e.g. Knight 2001). Leonidou *et al.* (2002)

notice that there appears to be a strong association between export marketing strategy and export performance measures. However, there is a need for more studies concentrating on causality characteristics between capabilities, internationalization strategies and performance.

Another limitation of our study is its cross-sectional nature. Hopefully, the further extensions of our work will have more longitudinal aspects included in the model as capabilities evolve through time. Although there are shortcomings, we believe that the findings in this study can contribute to the empirical body of research related to the international performance and capabilities of technology-based knowledge-intensive small firms. The use and exploration of the still little known PLS technique can also be useful for other related research.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
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10

ASSESSMENT OF THE IMPACT OF INTERMEDIATE AGRICULTURAL PROCESSING TECHNOLOGIES ON A RURAL COMMUNITY IN SOUTH AFRICA

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INTRODUCTION

South Africa is a country of extreme diversity in terms of the social and economic development of its population. It is not uncommon to find modern high-technology industries located next to poor traditional subsistence-farming communities. The economic development of such communities presents a unique challenge to community leaders and government agencies. There is growing concern about the level of underdevelopment of rural communities and one measure that has been considered is the introduction and promotion of the use of intermediate agricultural processing technology (IAPT).

In this study, impact assessment of IAPTs for cereal crops was conducted at the Vergelegen rural African community in the Limpopo (Northern) Province of South Africa. The province is mostly semi-arid, and is characterised by problems of drought, animal disease, lack of water for humans and livestock, and depleted underground water resources. The Limpopo province is the poorest region in South Africa with a GDP per capita of R1266 (Development Bank of Southern Africa 1993). It has the lowest degree of urbanisation (12.1%) and is predominantly a rural region where agriculture plays an important role (Mekuria and Moletsane 1996).

Subsistence farming with cereal crops (maize, sorghum, etc.) is very important to the livelihood of the poor and to the general economy of this area (Council for Scientific and Industrial Research - Food Science and Technology 1999). The community use the seeds of these crops for making meals, porridges, cakes and beer. The processing of the seeds (shelling, threshing, milling, drying and storage) has been and remains a serious problem to farmers. The processing of these crops is still predominantly done by traditional methods that are unproductive, laborious, time consuming, unhealthy and often result in losses. Rwelamira (1997) reported that inadequate access to improved technology has been one of the factors contributing to poverty and food insecurity in the rural areas, and the Limpopo Province in particular

It is a common view that IAPTs should improve the economy and productivity of the rural fold. It was therefore decided to do an assessment of the impact of IAPTs on a rural community in the Limpopo Province of South Africa.

INTERMEDIATE TECHNOLOGY AND RURAL DEVELOPMENT

Intermediate agricultural technology has been described as a middle way between traditional and modern – a technology between the sickle and the combine harvester (Schumacher 1973). Such technologies can be more sophisticated and durable adaptations of traditional technologies (such as improved fishing boats or mini-hydroelectric schemes), or they can be simpler scaled-down versions of modern technologies (such as small industrial plants processing oil seed crops or raw cotton).

Traditional methods of separating food grain from the pod (shelling) or from the stock (threshing) consist of rubbing, trampling or beating the crop. Traditional methods for shelling or threshing, especially trampling by animals, vehicle wheels or by foot, are reported to cause heavy losses, since a percentage of the grain is crushed, and impurities are mixed with the grain (Food and Agricultural Organisation of the United Nations 1989). IAPT such as simple hand-held wooden shellers and a wide range of small manual and engine operated shellers are manufactured commercially and are widely used.

Grain has to be ground to produce a meal. Pounding with a pestle and mortar is a widely used traditional method; another is to grind the grain between two stones. Dry milling is more common than wet milling, although flint-type maize is sometimes milled wet. IAPT such as small-scale hand-operated or engine-powered mechanical dry-milling is widespread in African villages. The range and capabilities of these milling machines vary considerably. Hammer mills powered by petrol or diesel engines have been installed in many trading centres (Food and Agricultural Organisation of the United Nations 1989).

Grains are traditionally stored either threshed or unthreshed in a variety of containers or underground pits. The main constraint of most structures for storing grain is that they do not allow for sufficient ventilation and therefore drying is required before grain can be stored safely. In the traditional drying of sorghum, the harvested heads are generally left in the sun to dry. Where sun drying is not possible, the heads are often placed above a fire to dry on special rigs, known in Tanzania as "ngoko". IAPT in the form of artificial drying techniques has had some success in West Africa. Several forced air dryers like continuous flow dryers, storage dryers and batch dryers have been introduced for drying maize grain. Improved shelled-grain storage structures for small producers in dry and humid climates have also been developed and introduced. They are made of durable materials such as metal and cement. Large-scale farmers and traders store shelled maize in bags in ventilated warehouses for ease of handling (Food and Agricultural Organisation of the United Nations 1989).

The aim of IAPT is to enable people to become self-sufficient and preferably to also create surpluses that they can reinvest in their families, businesses and communities. Therefore great emphasis is placed on sustainable income-generation. Extra production and productivity can provide more income, but also more choices, more self-respect, and less dependency.

RESEARCH METHODOLOGY

The specific objectives of this study were to:

- determine the population characteristics and existing agricultural processing activities carried out by households in the rural community.
- assess the impact of the adoption of IAPTs on the community and compare the benefits between the intermediate versus traditional processing techniques.
- identify the constraints to the adoption of IAPTs.

Impact assessment is a systematic process of reviewing or examining the differences or changes that development interventions have made on the lives of people in a given environment. Impact assessment therefore seeks to determine whether development assistance efforts have facilitated improvement in the overall quality of life of target groups, or not.

The target area of this study was the Vergelegen rural community near the town of Janefurse in the Limpopo Province of South Africa. The choice of Vergelegen as the target area for this study, was based on the objectives of the research and on the knowledge of the activities in the area from available reports and informal discussions with researchers of government departments and non-governmental organisations, that have been conducting research in the area. The research consisted of structured interviews conducted by trained local interviewers with 80 households selected by systematic random sampling from a population of 520 households. This satisfies the recommended range of 10-20% of the total population (Perret 1999).

Data collection consisted of the collection of published statistics and data, structured interviews by trained local interviewers using a questionnaire as well as direct observation and measurement. The guidelines on the building of research questionnaires, as recommended by Trochim (1999) and Perret (2000), were used in designing the questionnaire for this study. Questions were formulated using a structured format to reflect all the objectives of the study. The data analysis was done by means of descriptive and inferential statistics.

The interviews were conducted during the period January - April 2000 by eight trained local interviewers, who comprised staff from the regional department of agriculture as well as teachers in the community. After the interviews, a survey was carried out to identify and locate the existing processing technologies for maize and sorghum crops in the community as indicated by the households in the questionnaire. This included the traditional techniques and IAPTs such as maize shellers, sorghum threshers, milling machines and storage equipment.

PROFILE OF THE VERGELEGEN COMMUNITY

Vergelegen is a Sesotho-speaking rural African community in the Limpopo (Northern) Province of South Africa. We found that the majority (53%) of the heads of households were 60 years old and above, and almost all (96%) were married. The majority (57%) of the heads of households were females, whose husbands worked in cities and towns and visited their families only occasionally. On average about 6 persons live in a household and 6% of the male heads of households had two wives.

We found that the majority (78%) of households were engaged in subsistence farming activities. However, only 31% of household's income came from farming. The highest income came from old-age pensions (50%), while the rest came from salaries and wages (14%) and trading (4%). Farms are generally small: 61% of respondents had farm sizes less than 5 hectares, 33% between 5-10 hectares, and 6% over 10 hectares. It is a very traditional community where households have on the average been farming for the past 22 years. 87% of respondents acquired their farmland by inheritance, 10% by leasing and 3% by purchase.

We found that 44.4% of the households grow maize, 21.9% grow sorghum, 42.3% grow millet and 3% grow oil beans. The agricultural processing activities carried out by the farmers are shelling, threshing, milling, drying and storage of maize, sorghum and millet crops. Almost all (98.8%) of the respondents were involved in one or more of these processing activities.

Table 1 : Agricultural processing technologies used by the Vergelegen community.

Traditional processing methods	**Intermediate processing technologies**
Maize shelling	
• By hand • Beating with sticks • Rubbing with stones	• Shelling with tractor wheels • Mechanical Maize Sheller powered by a tractor
Threshing of sorghum	
• Beating with sticks	• Threshing with tractor wheels • Mechanical thrasher
Milling of grain	
• Grinding stones	• Milling machine powered by a 24 Hp diesel engine • Milling machine powered by a 2.2 kW electric motor
Drying of grain	
• Sun drying	• None
Storage of grain	
• "Seshego" grain baskets • Bags	• Drums and tanks

Almost all (96%) of the respondents use traditional methods for the processing activities. Most (86.5%) of the respondents shell their maize by hand. Almost all (95.8%) of the respondents thresh their sorghum by beating it with sticks and 98.6% of the respondents mill their sorghum crops with grinding stones. All the respondents dry their crops by solar radiation and mix it with a preservative made from the ash of Aloe plants before storage. Most (63.6%) of the respondents store their grains in bags, and a few (3.9%) still store their crops in traditional grain baskets, known as "Seshego".

A survey was carried out to identify and locate the existing IAPTs used by the community. The traditional techniques and IAPTs that were found are shown in Table 1. The use or "adoption" of IAPTs was generally low. In some cases traditional methods and IAPT were used together, for example many respondents first allowed the wheel of a tractor to roll over heaps of maize before completing the shelling by hand. The highest levels of adoption were of milling machines (55%) and storage of crops in drums and tanks (32.5%). The majority of households in the community do not own any IAPTs. The only technologies that were owned by a few households were the maize sheller and milling machines.

IMPACT ASSESSMENT

The impact of the adoption of IAPTs on physical strain, product quality, productivity, profit, and income level was assessed. Some of the problems highlighted by the respondents in the use of traditional techniques were physical strain resulting in aches and pains, tiresome, labour intensive, time consuming, lack of wind for winnowing, poor quality of meal (coarse texture, contamination with stone grit and sand), weather fluctuations, rodent and insect (weevil) attacks, rotting of crops and a scarcity of storage vessels.

The output rate and efficiency of shelling is much improved by the use of IAPTs as shown in Table 2. The use of IAPTs also substantially improved the output rate and quality of meal as shown in Table 3.

Table 2: Shelling efficiency (maize).

Parameter	**Traditional**	**Tractor wheels**	**Maize sheller**
Grain output kg/h	13	31	80
Grain damage (% damaged)	1.58%	15.2%	1.55%
Efficiency (% shelled)	96%	74%	93%

The impact of IAPT on income level and profit could not be assessed directly, as the subsistence farmers were unable to quantify their earnings from their farming activities. We were only able to obtain their perceptions of the impact of these technologies on income level and profit. The majority of respondents indicated that in their view the use of IAPT has or would have a high impact on increased income levels and profit generation. Very few indicated that it would have a low impact. The response frequencies are shown in Table 4.

Table 3: Flour output from milling (sorghum).

Parameter	**Traditional**	**Milling machine 1**[1]	**Milling machine 2**[2]
Flour output kg/h	4	50	211
Particles >1000 μm	36%	13%	0.23%
Particles <150 μm	11%	13%	56%
Losses	29%	17%	12%

[1] Milling machine powered by a 2.2 kW electric motor.

[2] Milling machine powered by a 24 Hp diesel engine.

Table 4: Farmers' perceptions of the impact of IAPTs on income level and profit

Indicators of impact	**Activities**	**Impact with IAPT**		
		High	**Medium**	**Low**
Increased income level	Maize Shelling	61.2 %	38.8 %	0 %
	Sorghum Threshing	64.4 %	35.6 %	0 %
	Milling	62.3 %	37.7 %	0 %
	Drying	55.8 %	44.2 %	0 %
	Storage	81.6 %	18.4 %	0 %
Increased profit generation	Maize Shelling	56.6 %	43.4 %	0 %
	Sorghum Threshing	60.0 %	38.0 %	2.0 %
	Milling	53.2 %	45.2 %	1.6 %
	Drying	56.5 %	43.5 %	0 %
	Storage	73.2 %	26.8 %	0 %

AWARENESS AND ADOPTION OF INTERMEDIATE TECHNOLOGIES

The survey showed a moderate level of awareness of IAPTs: 69.6% of the respondents were aware of milling machines, 51.2% of storage equipment, 43.8% of maize shellers and 41.8% of sorghum threshers. Only the awareness of dryers was low, with 11.4% of respondents indicting an awareness of them. The respondents indicated that they knew about these technologies through extension agents, friends and relatives. 30.1% of the respondents indicated that extension agents visit them very often, 35.6% indicated that they are visited often and 34.2% indicated that they have never been visited.

With the exception of milling machines and storage equipment, which was adopted by 55% and 32.5% of the respondents respectively, there was a very low level of adoption of other IAPTs: 2.5% adopted maize shellers, 1.3% adopted sorghum threshers, and none of the respondents adopted dryers. Levels of awareness and adoption are shown graphically in Figure 1. In the cases of three of the five technologies, adoption levels were very low notwithstanding the moderately high levels of awareness of these technologies. It is clear that awareness is a necessary, but not a sufficient condition for adoption.

Figure 1. Awareness and adoption of IAPTs.

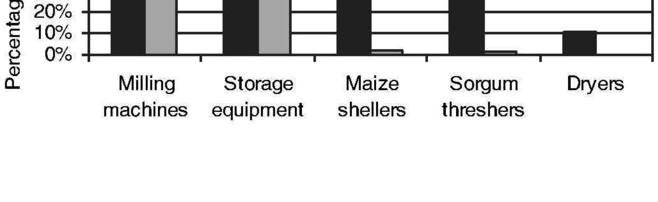

Table 5: Constraints encountered by respondents with the adoption of IAPTs

Technologies	Constraints	**Respondents**
Maize shellers	Expensive	29.4 %
	Not accessible	41.2 %
	Not familiar / Not available	27.9 %
	Poor harvest	1.5 %
Sorghum threshers	Expensive	23.9 %
	Not accessible	40.3 %
	Not familiar / Not available	28.4 %
	Low production of sorghum	4.5 %
Milling machines	Expensive	20.7 %
	Not accessible	44.8 %
	No white farmer (with mill) nearby	34.5 %
Dryers	Expensive	19 %
	Not accessible	42.9 %
	Not familiar / unknown	38.1 %
Storage equipment	Expensive	16.4 %
	Not accessible	49.2 %
	Poor harvest	1.6 %
	No co-operative stores and grain silos	16.4 %
	Not available	16.4 %

Those respondents that were aware of IAPTs, indicated a variety of constraints to adoption: 91.2% indicated that IAPTs are not accessible, 85% indicated that they are costly to use, 75% indicated that they are not affordable, 62.5% indicated that they are not transportable and 61.2% indicated that the technologies are risky to use. The response frequencies are shown in Table 5.

CONCLUSIONS

We found that the Vergelegen community consists mainly of elderly people, of whom the majority were female. Subsistence farming, predominantly by traditional techniques, was a major source of livelihood for the community. The majority of households in the community do not own any IAPTs. The only technology that was owned by a few households was the maize sheller and milling machines. Traditional processing techniques were found to be unsatisfactory in terms of physical strain, quality and quantity of output, time wastage, laborious process and the susceptibility of crops to rodent and insect infestations during storage.

There was a moderate level of awareness of most IAPTs. With the exception of milling machines and storage equipment, there was a very low level of adoption of other IAPTs. The moderate level of awareness of IAPTs was a constraint to adoption, but it was not the only constraint. Other common constraints to adoption experienced by the majority of the farmers, were inaccessibility, unaffordability, high cost of usage and risks in usage.

Inadequate enlightenment by extension officers on the availability and usage of IAPTs and the traditional nature of the community with a high proportion of old women as heads of households, contributes to the low level of adoption of IAPTs.

RECOMMENDATIONS

The study has shown that the introduction of IAPTs could be very beneficial for rural farming communities such as the Vergelegen community. Although IAPTs such as milling machines and maize shellers have already been introduced, many households have not adopted them. The diffusion of such IAPTs should be given a high priority. The development of an awareness strategy to enlighten the farmers about the benefits of adopting IAPTs is necessary. However, as most of the rural households have limited or no capital to purchase IAPTs, it is recommended that the introduction of low cost alternative IAPTs such as manually-operated maize shellers and mills should be investigated.

Communal ownership of IAPTs including small grain silos located at co-operative stores, that are affordable and accessible to the community, should be promoted. The establishment of farmer's co-operative societies within the framework of the community, should be encouraged and facilitated by local authorities. This will enable them to obtain credit facilities from financial institutions to purchase IAPTs.

Linkages and relationships between agricultural extension officers, post-harvest technology experts and the rural farmers should be strengthened. This will aid the dissemination and introduction of new processing technologies to the rural community. The Government's agricultural policy should also be reviewed to incorporate the promotion and introduction of IAPTs in rural farming communities.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

11

A RE-ANALYSIS OF WORLD COMPETITIVENESS USING IMD - SCIENCE AND TECHNOLOGY -

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INTRODUCTION

The "World Competitiveness" ranking compiled by IMD is widely quoted by various bodies, particularly in Japan. However, its contents have not been deeply analyzed, are superficially used, and are often quoted in a misleading way. In any cases, there has been no detailed analysis. Furthermore, S&T competitiveness has not been presented since 2001. Concerns regarding this issue are strong, and therefore, there is a great demand to address it in Japan.

This research analyzes S&T World Competitiveness (STWC, or, for convenience, 'Competitiveness') using the criteria[5] of IMD reports, and to supply results for an appropriate understanding. In other words, the goals are:

1. To apply multivariate analysis to criteria concerning S&T of IMD to clarify the structure of the criteria used. IMD adds the values of many criteria to obtain the level of competitiveness. Structural analysis of the criteria used is required

[5] The variables or statistics used in the IMD reports are called "criteria."

although we approve of the method and appreciate its usefulness. We also believe that trend analysis of the criteria clusters comprising the structure is necessary.

2. To examine the content, the meaning of each criteria cluster is elucidated. Finally, we obtained four criteria clusters: (a) S&T Power, (b) S&T Activity Density, (c) National Technology Management, and (d) S&T Human Resources.
3. To clarify the relationships among the clusters.
4. To identify appropriate criteria that comprise STWC based on the analysis mentioned above, and to develop their indicators. We analyzed trends in STWC of the chosen countries for international comparison.
5. To develop an indicator of each criteria cluster. We also compared the trends of the selected countries internationally.
6. To analyze trends in individual criteria, and to compare them internationally.
7. To clarify the problems with the criteria used and the method applied for STWC for better use of Competitiveness.

DATA USED

IMD has published its WCY since 1986. However, the number of variables has increased since 1988. Because IMD calls these variables criteria, we also use this term. S&T was one of eight fields in the reports by the 2000 Yearbook. However, all criteria have been integrated into four fields ("Input Factors" in WCY) since the 2001 Yearbook, and S&T World Competitiveness has never been calculated. Most criteria composing S&T World Competitiveness now belong to the "Scientific Infrastructure," a sub-factor composing the "Infrastructure" input factor, while many others belong to "Technological Infrastructure." In addition, the publication year of the Yearbook differs from the measurement year of the criteria, and furthermore, the measurement year varies in the same Yearbook among criteria because IMD tries to use the most recent data. Moreover, some questions are slightly different between 1988 and 2002, although their titles are the same.

Tab. 1 S&T Criteria Used

No.	Criteria (abbreviation)	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02
1	Total Expenditure on R&D (RdExp)	-	0	0	0	0	0	0	0	0	0	0	0	0	-	-
2	Total Expenditure on R&D per capita (RdePc)	-	0	0	0	0	0	0	0	0	0	0	0	0	-	-
3	Total Expenditure on R&D % (RdePg)	-	0	0	0	0	0	0	0	0	0	0	0	0	-	-
4	Business Expenditure on R&D (BusRde)	-	0	0	0	0	0	0	0	0	0	0	0	0	-	-
5	Business Expenditure on R&D per capita (BusRdePc)	-	0	0	0	0	0	0	0	0	0	0	0	0	-	-
6	Total R&D Personnel Nationwide (RdPrs)	-	0	-	0	0	0	0	0	0	0	0	0	0	-	-
7	Total R&D Personnel Nationwide per capita (RdpPc)	-	0	-	0	0	0	0	0	0	0	0	0	0	-	-
8	Total R&D Personnel in Business Enterprise (BusRdp)	-	0	-	0	0	0	0	0	0	0	0	0	0	-	-
9	Total R&D Personnel in Business Enterprise per capita (BusRdpPc)	-	0	-	0	0	0	0	0	0	0	0	0	0	-	-
10	Qualified Engineers (QualEng)	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0
11A	Information Technology Skills (InfoTek)	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
11B	Computer Literacy	-	-	-	-	0	0	0	0	-	-	-	-	-	-	-
12	Technological Cooperation (TekCoop)	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
13A	Knowledge Transfer (CuCoop)	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
13B	Research Cooperation	-	-	-	-	0	0	0	0	0	0	0	-	-	-	-
14	Development and Application of Technology (TekDevApl)	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
15A	Relocation of R&D Facilities (RdFcl)	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
15B	Relocation of Production	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-
16	Nobel Prizes (Nbl)	0	0	0	-	-	0	0	0	0	0	0	0	0	0	-
17	Nobel Prizes per capita (NblPc)	0	0	0	-	-	0	0	0	0	0	0	0	0	0	-
18	Basic Research (BasRes)	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0
19	Science and Education (SciEdu)	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
20A	Interest in Science and Technology (StYouth)	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
20B	Engineering Science	-	-	-	-	0	0	0	0	-	-	-	-	-	-	-
21	Patents Granted to Residents (PtnRes)	-	0	0	0	0	0	0	0	0	0	0	0	-	-	-
22	Changes in Patents Granted to Residents (ChngPtn)	-	0	0	0	0	0	0	0	0	0	0	0	-	-	-
23	Securing Patents Abroad (PtnAbrd)	-	0	0	0	0	0	0	0	0	0	0	0	-	-	-
24A	Patent and Copyright Protection (PtnProt)	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
24B	Intellectual Property	-	-	-	0	0	0	0	0	0	0	0	-	-	-	-
25	Number of Patents in Force (PtnFrc)	-	0	0	0	0	0	0	0	0	0	0	0	-	-	-
26	Financial Resources (FinaRes)	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0

IMD used 26 criteria for STWC in the 2000 Yearbook. They are divided into two groups as follows.

1. Hard criteria: statistics such as research and development (R&D) expenditure and R&D personnel. There are 15 criteria.

These can be further divided into two sub-groups, that is, absolute and relative. The hard absolute criteria are statistics of the absolute type, such as R&D expenditure and R&D personnel, while the hard relative criteria are obtained by dividing the hard absolute criteria by the population or GDP. Examples are R&D expenditure per GDP and R&D personnel per capita.

2. Soft criteria: questions of the questionnaire survey by IMD. The measurement values depend on responses to the questions. There are eleven criteria. The responses are standardized as follows: the best by ten, the worst by zero, and the moderate by five.

The above table shows the use or existence of these criteria by measurement year. The symbol, (o), indicates the existence of the criterion, while the sign, (-), indicates non-existence. The soft criteria are underlined. When the contents of the questions with the same title are different, we attach the branch sign of A or B to the same number of criteria. In the case of the Nobel Prize, the mean values of the past several years were used in the early-published Yearbooks. Abbreviations for the criteria are shown in parentheses.

STRUCTURE OF THE CRITERIA: RESULTS OF THE MULTIVARIATE ANALYSIS

We analyzed relationships among criteria composing STWC of IMD to clarify their structure. To apply factor analysis,

- We used the criteria in the 2001 Yearbook.
- First of all, we expected to use all 26 criteria. However, we decided not to adopt the criterion, "Number of Patents in Force (PntFrc)" firstly because some advanced countries such as Italy, New Zealand, and Britain lacked its values, and secondly and more importantly, because it had only very low correlation with other criteria.
- We analyzed all countries that had measured values of all 25 criteria. As a result, 33 countries were our targets of analysis.
- The United States lacked values of the criteria concerning the number of R&D personnel. The world average seemed to be substituted for the missing value

according to the IMD Yearbook. That is, the value of the missing criterion was presumed to be 0. We thought that this assumption was inaccurate. Therefore,

- In the case of the number of R&D personnel (RdPrs) of the United States, we estimated its 1999 value by simple linear regression analysis using statistics in 1991, 1993, 1999. We used the following estimation formula.

  RdPrs = -12,581,400 + 6,800Y, R = 0.930, R^2 = 0.865,

  where, RdPrs = "Total R&D Personnel Nationwide," and Y=Year.

  As a result, we obtained 1,011,800. In addition, after this value was divided by the population, "Total R&D Personnel Nationwide per capita (RdpPc)" in 1999 = 3.704 was obtained.

- The values of "Total R&D Personnel in Business Enterprise (BusRdp)" have never existed in the United States. The criterion, RdPrs, analyzed above had the highest correlation coefficient. Therefore, we estimated the value of BusRdp in 1999 using the following formula:

  BusRdp = 36.222 + 0.59521 x RdPrs, R= 0.971, and R^2 = 0.942.

  To obtain the formula, we used the data of certain developed countries, that is, France, Germany, Japan, and the U.K., because of the great similarity among them.

- "Total R&D Personnel Nationwide per capita (RdpPc)" had the closest correlation with "Total R&D Personnel in Business Enterprise per capita (BusRdpPc)." The expectation formula was BusRdpPc = -0.2460 + 0.59496 x RdpPc with R = 0.926, and R^2 = 0.858. To develop this formula, we used the data of all countries except the United States, that is, 32 countries, because their standard deviation seemed small and steady.

After the set of these operations, we obtained a data matrix of 25 criteria and 33 countries, which had no missing values. To understand the quantitative relationships among the criteria, we applied factor analysis to the data matrix. The factor loadings obtained by the principal axis method were rotated by Varimax rotation. The figure below shows the factor loadings of the first and the second factors. The accumulated ratios of the Eigen values were 54.0% in the first factor and 76.9% in the second factor.

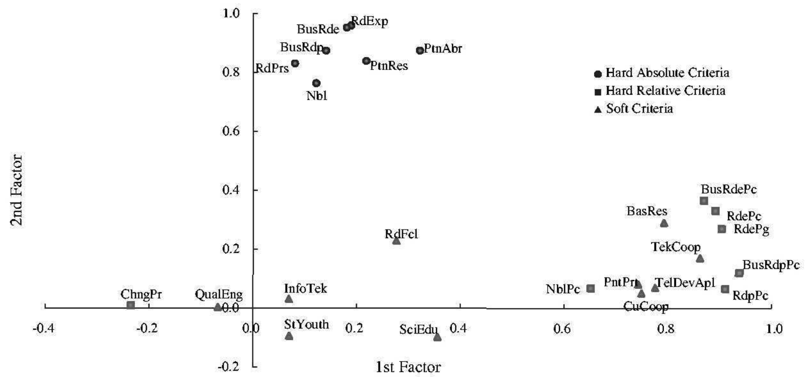

Fig. 1 Factor Loadings of the S&T Criteria

This figure clearly shows the following points.

- All hard absolute criteria are located close to each other in the upper part of the figure, and separated from the other criteria. They compose one cluster.
- Similarly, all hard relative criteria except one criterion are also located close to each other on the right-hand side of the figure. They compose another cluster, which is statistically independent from the first cluster.
- The criterion, "Changes in Patents Granted to Residents (ChngPtn)," is an exception to the second cluster because it is located at the left-hand end, that is, the opposite side of the cluster. ChngPtn is a kind of growth rate, and therefore different from the other hard relative criteria that are not the growth rate type but the density type. We believe this was why ChngPtn was located separate from the other relative criteria. We also found the quantitative analysis very useful and practical. In our analysis, this criterion is hereafter not adopted.
- It is possible and might be useful to calculate the growth rates of some hard criteria to add them to the S&T criteria. They might improve the possibility of the S&T criteria reflecting the STWC situation of individual countries more accurately. This is an attractive subject for future study.

- The soft criteria are located along the X-axis, and show different behaviour from the hard criteria. This indicates that the soft criteria have different quantitative characteristics from the hard criteria, and therefore, that it is appropriate to analyze both groups of criteria separately. However, it is necessary to recognize that some of the soft criteria are closely related to the hard relative criteria.

Structure of the Hard Criteria

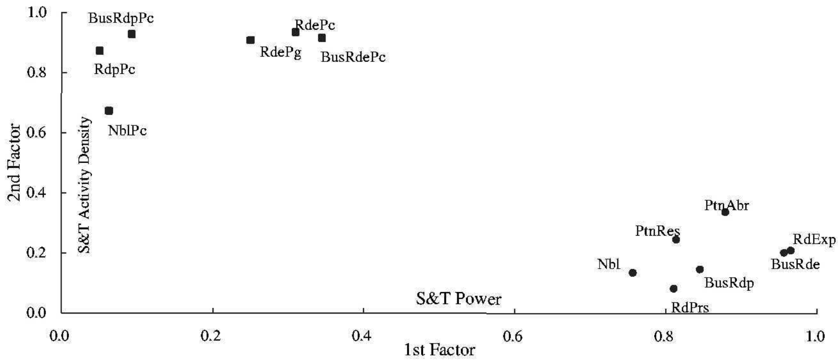

Fig. 2 Factor Loadings of the Hard Criteria

We applied factor analysis to the hard criteria that compose STWC by IMD, where we excluded the criterion, "Changes in Patents Granted to Residents (ChngPtn)," after considering the characteristics of the criteria as mentioned above. The factor loadings obtained by the principle axis method were rotated by Varimax rotation. The accumulation ratios of the Eigen values were 57.1% in the first factor, and 80.2% in the second factor. The analysis was applied not only to the 2001 Yearbook but also to the criteria of the measurement years from 1989 to 2000. We omitted these introductions because we obtained very similar results to those of the 2001 Yearbook.

The figure above shows the results. It indicates that the hard absolute criteria and the hard relative criteria are clearly separated, as expected from the previous analysis, although the X- and the Y-axes are reversed. Based on the characteristics of the criteria, we called the cluster of hard absolute criteria, "S&T Power," while we called the cluster of the hard relative criteria, "S&T Activity Density."

Structure of the soft criteria

Factor analysis was applied to the soft criteria (see the table below), and the principal axis method and Varimax rotation were similarly executed. The accumulated ratios of the first and second factors were 50.4% and 70.4%, respectively. All the soft criteria in the 2001 Yearbook were measured in 2001.

Tab. 2 S&T Soft Criteria

No.	Criteria
10	Qualified Engineers, "Qualified engineers are not or are available in your country's labor markets" (QualEng)
11	Availability of Information Technology Skills, "Qualified information technology employees are not or are available in your country's labor market" (InfoTek)
12	Technological Cooperation "Technological cooperation is lacking or is common between companies" (TekCoop)
13	Company - University Cooperation "Technology transfer between company and universities is insufficient or is sufficient" (CuCoop)
14	Development and Application of Technology "Development and application of technology is constrained or is supported by the legal environment" (TekDevApl)
15	Relocation of R&D Facilities "Relocation of R&D facilities is or is not a threat to the future of your economy" (RdFcl)
18	Basic Research, "Basic research does not or does enhance long-term economic and technological development" (BasRes)
19	Science and Education "Science is not or is adequately taught in compulsory schools" (SciEdu)
20	Science and Technology and Youth "Science & technology does not interest or interests the youth of your country" (StYouth)
24	Patent and Copyright Protection "Patent and copyright protection is not or is enforced in your country" (PntPrt)
26	Financial Resources "Lack of sufficient financial resources constrains or does not constrain technological development" (FinaRes)

After the analysis, we obtained the figure below. It shows that the soft criteria can be divided to the two following clusters, although there is an exception.

1. The criteria belonging to the first cluster are located on the right-hand side of the figure; in other words, they have large factor loadings of the first factor. "Development and Application of Technology," "Financial Resources," "Company - University Cooperation," "Technological Cooperation," "Basic Research," and "Patent and Copyright Protection" belong to this cluster. A common characteristic among these criteria is technology management at national level. Therefore, we named the cluster "National Technology Management."

2. Those belonging to the second cluster are located in the upper part. “Science and Education,” “Qualified Engineers,” “S&T and Youth,” and “Availability of Information Technology Skills” belong to this cluster. A common characteristic is fostering S&T human resources. Therefore, we named it “S&T Human Resources.”

The criterion, "Relocation of R&D Facilities," is located near the middle of both clusters. On the one hand, it has the characteristic of technology management at national level because it is one of most important national S&T strategies. On the other hand, the criterion has also the characteristic of fostering S&T personnel. With the relocation of R&D facilities, how to foster new talent for relocated facilities, how to hire excellent overseas researchers, how to establish cooperation teams, and so on, are very important. In short, this criterion has two simultaneous characteristics. If this is so, it is appropriate to assume the degree of contribution to each cluster to be half (0.5), respectively.

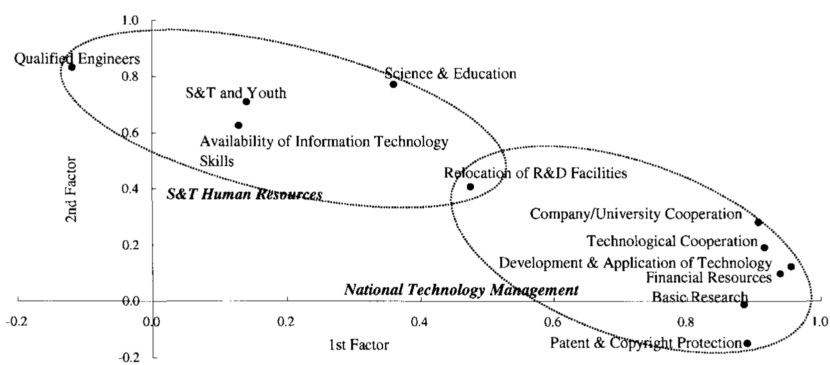

Fig. 3 Factor Loadings of the Soft Criteria

We applied similar factor analysis to the criteria measured in the same year from 1992 to 2002, respectively (see Tab. 1). As a result, we obtained very similar results to the criteria in the 2001 Yearbook as introduced above in the case of “National Technology Management,” while the number of criteria that compose “S&T Human Resources” decreases the further back into the past. Therefore, they have exactly the same structures. The reason is that the number of criteria has increased over time and that their meanings have changed.

The criterion structure of the 2002 Yearbook is very similar to that of the 2001 Yearbook. In addition, based on the above-mentioned analyses, the criterion structure obtained from the 2001 Yearbook could be used as a standard for all years from 1992 to 2002. The reasons are first, that number of criteria has increased, and second, that the reliability of each criterion has improved due to experience in conducting surveys and analyzing the responses.

Relationships among Related Indicators

We developed the following indicators.

1. S&T World Competitiveness
2. S&T Power
3. S&T Activity Density
4. National Technology Management
5. S&T Human Resources

To calculate all the indicators except "S&T World Competitiveness," we used the factor scores of the 33 countries that were the results of the factor analyses. The indicator, "S&T World Competitiveness," is calculated as the summation of the other four indicators. We first analyzed the correlation among the indicators, and second, their relationships with GDP and the population (see the table below).

Tab. 3 Relationships among Related Indicators

	S&T World Competi-tiveness	S&T Power	S&T Activity Density	National Technology Management	S&T Human Resources
World Competitiveness	1.000	0.648	0.846	0.883	0.404
S&T Power	0.648	1.000	0.401	0.326	-0.020
S&T Activity Density	0.846	0.401	1.000	0.791	0.121
Nationl Technology Management	0.883	0.326	0.791	1.000	0.297
Human Resources	0.404	-0.020	0.121	0.297	1.000
GDP	0.616	0.962	0.330	0.336	-0.020
GDP (ppp)	0.465	0.878	0.158	0.198	-0.036
Population	-0.095	0.187	-0.242	-0.212	-0.003
GDP per capita	0.773	0.445	0.856	0.754	0.009
GDP (ppp) per capita	0.747	0.339	0.763	0.796	0.130

Correlation coefficients over 0.75 are underlined except in the case of "World Competitiveness." Among the indicators developed, "S&T World Competitiveness" has a strong relationship with the other three component indicators except "S&T Human Resources." Only one pair, that is, "S&T Activity Density" and "National Technology Management," have strong correlation with each other, while "S&T Human Resources" is isolated from any other indicator. This implies that fostering S&T human resources influences S&T activities in the long-term. The table shows that population has no connection with indicators related to S&T. On the contrary, GDP is related more strongly to "S&T Power" than to "S&T World Competitiveness," while GDP per capita is also related firstly to "S&T Activity Density" and secondly to "S&T World Competitiveness" and "National Technology Management." We focus on the last relationships because it implies that S&T activity density and national strategy for technology management contribute to national economic development and growth.

TRENDS IN S&T WORLD COMPETITIVENESS

First of all, we calculated "S&T World Competitiveness" using the IMD method. The calculation method was assumed because its details have not been published and they have changed. We applied the method to the 33 countries that have no missing values. Therefore, "S&T World Competitiveness" that we calculated must differ from the value that IMD would calculate using its own method. We then calculated "S&T World Competitiveness" using our own method based on the analyses as mentioned above. There did not seem to be much difference between the two methods. We then decided to calculate hereafter each indicator using our method.

S&T World Competitiveness Using the IMD Method Estimated

We estimated the IMD method to calculate "S&T World Competitiveness" as follows:

$$C_j = k_h\Sigma x_{hij}/s_{hi} + k_s\Sigma x_{sij}/s_{si}, \qquad (1)$$

where C_j is "S&T World Competitiveness" of Country j,

x_{hij} or x_{sij} is the hard (h) or soft (s) Criterion i of Country j,

s_{hi} or s_{si} is the standard deviation of the hard (h) or soft (s) Criterion i, and

k_h and k_s are the coefficients of the hard and the soft criteria. In fact, $k_h = 1/15$ and $k_s = 1/11$ in Year 2001, which means that both the hard and soft weights are equal.

The United States had the maximum value, and it was adjusted to 100. The other countries were adjusted proportionately. The results are shown in the figure below.

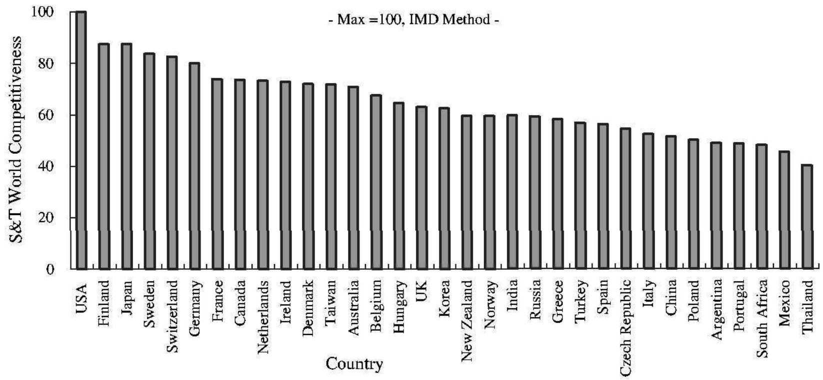

Fig. 4 S&T World Competitiveness

As the figure shows, the U.S. has the greatest S&T world competitiveness, followed by the second group, that is, Finland and Japan. Sweden, Switzerland and Germany compose the third group, but the difference between the first and the second groups is greater than that between the second and the third. Based on experience in developing and analyzing the "General Indicator of S&T (GIST)" (Niwa and Tomizawa, 1996, 1998; Tomizawa and Niwa, 1996), Japanese competitiveness may be overestimated. In fact, we can find more statistics for the input and industry in the criteria list, suggesting that such a judgment is not necessarily wrong.

S&T World Competitiveness Using our Modified Method

We modified the IMD method based on the results of the criteria analyses to calculate the "S&T World Competitiveness" as follows:

$$C_j = k_{hj}\Sigma x_{hij}/s_{hi} + k_{sj}\Sigma((x_{sij}-5)/s_{si}+5), \qquad (2)$$

where C_j, x_{hij}, x_{sij}, s_{hi} and s_{si} have the same meanings as mentioned above in Formula (1).

$k_{hj} = 1/ n_{hj}$ and $k_{sj} = 1/ n_{sj}$, n_{hj} and n_{sj} are the number of hard and soft criteria used for Country j.

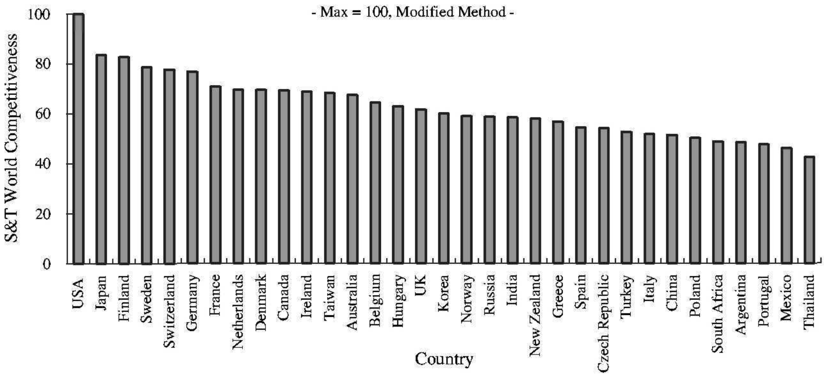

Fig. 5 S&T World Competitiveness

Because we did not use the criteria of missing values, n_{hj} and n_{sj} vary by country. Moreover, neither "Changes in Patents Granted to Residents (ChngPtn)" nor "Number of Patents in Force (PntFrc)" is adopted from the characteristics of these criteria. Furthermore, we assumed that five must be the fixed neutral value for all respondents because it is the middle of the continuum used for the questionnaire survey. Again, the United States had the maximum value, and it was adjusted to 100. The other countries were adjusted proportionately.

We can find only slight differences between both figures; r = 0.994. Firstly, the rankings of several countries are different, and secondly, the difference between the first and second groups of the second figure is slightly greater than that of the first. The second figure reflects more precisely the actual situation.

Time Trends in S&T World Competitiveness

We calculated S&T World Competitiveness as follows:

$$C_{jt} = k_{hjt}\Sigma(x_{hijt}-m_{hit})/s_{hit} + k_{sjt}\Sigma(x_{sijt}-5)/s_{sit}, \quad (3)$$

where C_{jt} is the "S&T World Competitiveness" of Country j and Year t,

x_{hijt} and x_{sijt} are the values of the hard (h) and soft (s) Criterion i of Country j and Year t,

m_{hit}, s_{hit}, and s_{sit} are the mean and standard deviation of the hard (h) and soft (s) Criterion i and Year t, respectively.

$k_{hjt} = 1/ n_{hjt}$ and $k_{sjt} = 1/ n_{sjt}$, n_{hjt} and n_{sjt} are the numbers of the hard and soft criteria used for Country j and Year t. They vary by country and year because we did not use missing values.

This formula indicates that the competitiveness is a mean of the so-called standardized values of the hard and soft criteria as the IMD Yearbooks introduced (IMD, 1986-2002). Furthermore, the competitiveness is calculated for each year.

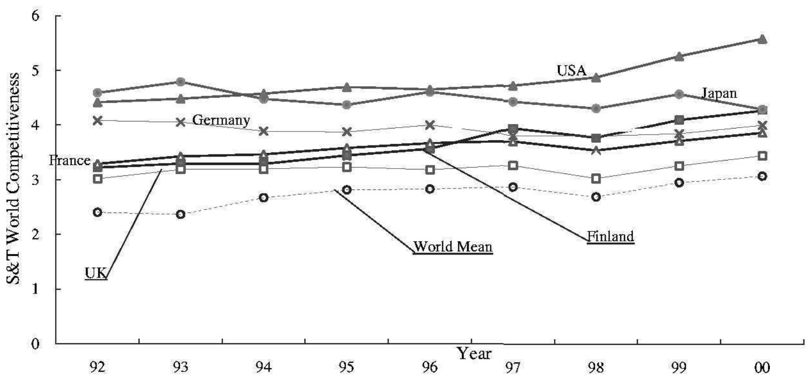

Fig. 6 S&T World Competitiveness

The figure above shows time trends in the S&T World Competitiveness of the selected countries from 1992 to 2000. This period was chosen based on total stability, that is, the number and balance of the criteria (see Tab. 1). The figure and our analysis reveal the following tendencies.

- Most of the selected countries have an increasing tendency.
- The S&T World Competitiveness of the U.S. shows the largest increase in the period among the selected countries. In particular, its growth ratio at the end of '90s is remarkable. Therefore, the gap between the U.S. and the other countries has expanded.

- The Competitiveness of Hungary is also remarkable, followed by Finland and China.
- Japan shows the greatest decreasing tendency, followed by Germany. Japan being in the leading position changed to the U.S. being in the leading position in the mid '90s. Moreover, other countries will catch up with Japan in the near future.
- India and Taiwan have increasing tendencies following the Hungary, Finland and China group.

TIME TRENDS IN COMPONENTS

Hard versus Soft Indicators

Our analysis indicates that the hard and soft criteria are statistically independent. The reason seems to be that they are different from each other in their definitions and measurement methods. A comparison of both criteria was necessary. For the comparison, we developed hard and soft criteria indicators. The former is the same as the first term of S&T World Competitiveness (Formula 3) and the latter is the same as the second.

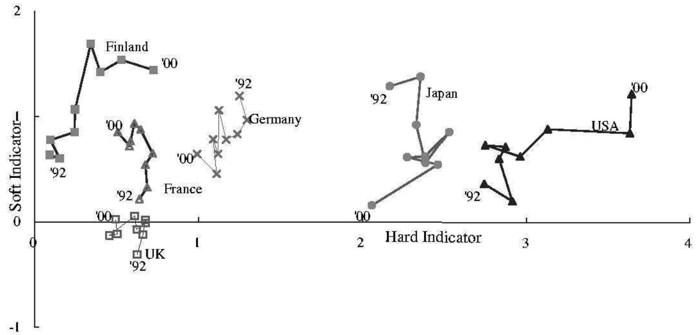

Fig. 7 Hard versus Soft Indictors

The figure above shows the indicators of the selected countries. Its horizontal and vertical axes show the hard and soft criteria, respectively. The figure and our analysis reveal the following:

- The selected countries seem to be stratified by the hard indicator. The reason is that the soft indicator fluctuates more greatly than the hard indicator in general.
- The United States dominates the other countries in the hard indicator. It has increased greatly in both the hard and soft indicators.
- At the end of '90s, Finland dominates in the soft indicator. It has increased greatly in both indicators like the U.S.
- Japan holds second hard indicator position, followed by Germany. Both countries have gone down in the soft indicator in this period. The Japanese decrease is greater than Germany's.
- The countries with low hard indicator values have improved their soft indicator values, except for Finland.

S&T Power versus S&T Activity Density

Our analysis above shows that the hard criteria are composed of two clusters, that is, S&T power and S&T activity density. Thus, we developed the following indicators.

S&T Power: $P_{jt} = k_{pjt}\Sigma(x_{pijt}-m_{pit})/s_{pit}$,

S&T Activity Density: $D_{jt} = k_{djt}\Sigma(x_{dijt}-m_{dit})/s_{dit}$,

where p and d indicate that the variables attached belong to "S&T Power" and "S&T Activity Density," respectively. The meanings of k, x, m and s are the same as those mentioned above.

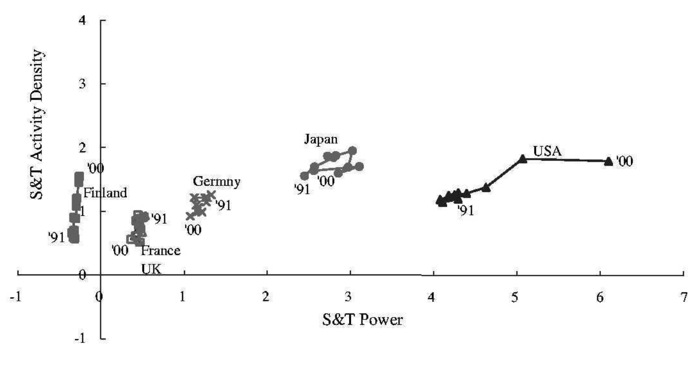

Fig. 8 S&T Power versus S&T Activity Density

The figure above shows time trends in both indicators for the selected countries. The figure is composed of the two axes, that is, the horizontal axis showing S&T Power and the vertical showing S&T Activity Density. Our analysis reveals the following:

- The United States dominates the other countries in S&T Power. In particular, it has greatly increased its value recently. Japan follows the United States and increased its value slightly in the period. Germany follows Japan, but has decreased slightly.
- Switzerland (not in the figure) heads the list of S&T Activity Density. The United States, Japan and Finland follow it in a group.

National Technology Management versus S&T Human Resources

According to our analysis, the soft criteria can be divided to two clusters, that is, National Technology Management and S&T Human Resources. The following are indicators that we developed.

National Technology Management: $M_{jt} = k_{mjt}\Sigma(x_{mijt}\text{-}5)/s_{mit}+0.5(x_{rjt}\text{-}5)/s_{rt}$,
S&T Human Resources: $H_{jt} = k_{hjt}\Sigma(x_{hijt}\text{-}5)/s_{hit}+0.5(x_{rjt}\text{-}5)/s_{rt}$,
where m and h indicate that the variables belong to "National Technology Management" and "S&T Human Resources," respectively. The meanings of x and s are the same as those mentioned above. $k_{mjt}=1/\ (n_{mjt}+0.5)$, $k_{hjt}=1/\ (n_{hjt}+0.5)$, where n is the number of related criteria.

Furthermore, r indicates the criterion, "Relocation of R&D Facilities." If the criterion is not measured, the second terms of both indicators are eliminated, and $k_{mjt}=1/\ n_{mjt}$, and $k_{hjt}=1/\ n_{hjt}$.

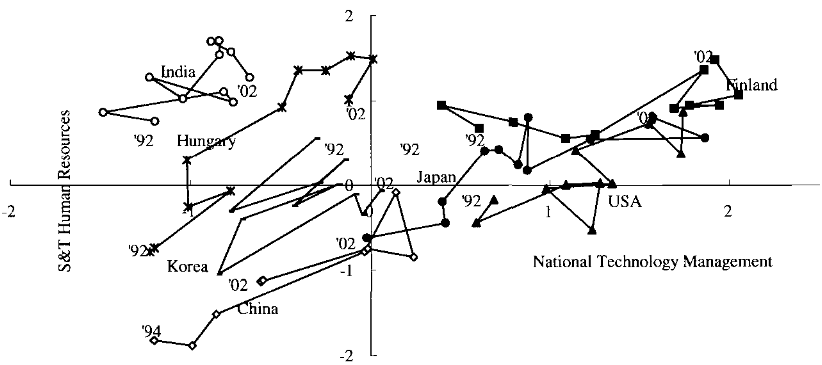

Fig. 9 Technology Management versus Human Resources

Time trends in both indicators are shown in the figure above, which is composed of the two axes, that is, National Technology Management and S&T Human Resources. We selected seven out of the 33 countries because it was convenient for grasping the trends.

- First of all, both indicators of each country change greatly, which suggests less stability, and thus the lower reliability of the soft criteria rather than the hard criteria.
- Recently, Finland has the greatest value of the indicator, "National Technology Management," followed by the United States. Both countries and Hungary change the indicator values most greatly in the period.
- In the case of the second indicator, "S&T Human Resources," India recently assumed the top position, followed by Hungary and the United States. These countries have the greatest changes in the indicator in the period.
- Japan has decreased in both indicators most greatly in the period. Germany (not in the figure) holds second place regarding greatest decrease, although it is not shown in the figure.

Time Trends in Individual Criteria

We analyzed time trends in each criterion to understand their recent situation. Only some of the results obtained are introduced. Firstly, we omit the hard criteria results because international comparison of these criteria can easily be found in other materials. Secondly, it focuses on Japan because the Japanese are well informed about the Japanese situation.

- First of all, many soft criteria of each country fluctuate over time, but they clearly reveal their approximate trends.
- On the one hand, Japan is consistently high level in the case of hard criteria regarding expenditure, personnel and patents except Nobel Prizes in the period, following the U.S. On the other hand, all soft criteria except "Qualified Engineers" and "Relocation of R&D Facilities" have declined in the period, in particular since the latter half of '90s. Here, we used not their direct values x_{ijt}, but their standardized values $(x_{ijt}-5)/s_{it}$.
- We should focus on the fact that the direct values of many soft criteria of Japan did not change greatly through '90s, while standardized values have decreased because their direct values in the other countries have increased.
- The following can be inferred. The Japanese respondents, mostly from industry, were asked for an absolute evaluation of the Japanese situation, but they often answered by comparing it with the situation of other developed countries, in particular, the United States. That is, the respondents gave not an absolute but a relative evaluation, for instance, in the case of "Company - University Cooperation." In this sense, the less change (or no decrease) in the Japanese values of the soft criteria implies that the measures produced definite results. The problem is that Japan's improvements have been too slow compared with those of other countries.
- In Japan "Science and Technology and Youth," "Company - University Cooperation," "Availability of Information Technology Skills," and "Science and Education" have negative standardized values in the early '00s, and the first two criteria went down under minus one STD (s) in '02. The others, excluding "Relocation of R&D Facilities," have positive standardized values, but within one STD in the same period. This shows very clearly the serious situation of Japanese S&T. As a result, Japan will certainly lose its second place in the near future.

As an example, we introduce trends in the soft criterion, "Basic Research," in the figure below. Its question is "Does basic research enhance long-term economic and technological development?"

- First of all, the criteria for all countries fluctuate over time, but they clearly reveal their approximate trends.

- The United States, Finland, Korea, and India have increased the criterion in the period. In particular, Korea jumped between '98 and '99. This means that these countries have strengthened recognition of their country's basic research, enhancing their long-term economic and technological development.
- China and Taiwan have the relative maximum points, between '97 and 2000 and in '95 in the case of China and Taiwan, respectively. China jumped between '96 and '97.
- Japan and Germany have decreased the criterion, although their direct values have not greatly changed. Switzerland has kept it approximately constant, although the trend was left out of the figure for convenience of observation.

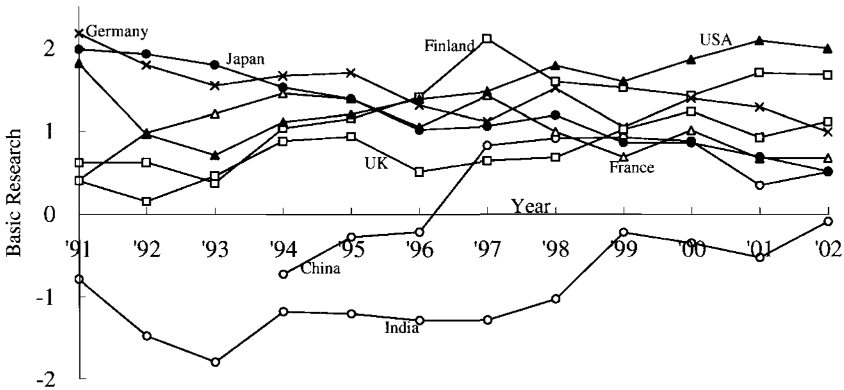

Fig. 10 - Basic Research

6. CONCLUDING REMARKS

Our analysis clarified the following points.

- First of all, analysis of the World Competitiveness Yearbook published by IMD proved very useful. The publication has made people in the world recognize the necessity and usefulness of measurement data, and this is a significant achievement. They have stimulated several countries with poor statistics to improve them. Furthermore, we used not only the results analyzed by IMD, but we also used directly the values of the criteria as materials for our analyses. IMD improves the criteria every year. Our analyses are greatly owing to the efforts of IMD in this respect.

- On the other hand, there are some problems. It is definitely necessary to sum up criteria with different characteristics, such as hard and soft criteria, to obtain World Competitiveness. However, it is necessary to analyze differences in these characteristics before summation. When we integrate a large number of criteria, a structural analysis of them is necessary before integration. Our analysis actually clarified that the criteria concerning S&T of IMD are classified into four statistically independent criteria clusters.
- There may be few hard criteria. It would certainly be very difficult to collect the criteria of many countries that can be compared. For instance, we gathered twelve hard absolute criteria to integrate the General Indicator of S&T as mentioned above, although we focused on only five developed countries.
- The Yearbook adopts only one criterion of the growth rate type. Of all hard absolute criteria, we can calculate growth rate-type criteria. It seems that growth rate-type criteria might show different aspects of competitiveness from the absolute and relative hard criteria. Adding growth rate-type criteria may be an improvement although prior analysis is necessary.
- There were more than 3,500 respondents to the questionnaire survey in total in the 2001 Yearbook. There were more than 140 returns, and the return ratio was about 13% in the Japanese case (Kitamura, 2002). This suggests the problem of reliability. The IMD Yearbook shows the survey organization of each country as a partner. However, this is insufficient. We ask IMD to open the population, the number of samples, and the number of respondents from each country.
- There are problems in the use of the results (Kitamura 2002). This might not be limited to Japan. Only the ranking is emphasized in Japan. However, it is necessary to recognize the position of each country in the distribution (see Figs. 4 and 5). In addition, the Japanese tend to focus on the results of specific individual soft criteria such as "Company - University Cooperation." They should also focus on trends in criteria clusters such as "National Technology Management." It may not be sufficient to use only some of the Yearbook. It is also necessary to analyze the original data for the purpose of use.
- We analyzed only the S&T Sub-factor in this paper, because of the strong Japanese interest in S&T (Niwa & Kuwahara, 2002, 2003). It is possible to easily expand the analysis to all criteria comprising World Competitiveness. Such an

analysis would greatly contribute to an overall structural grasp of global competitiveness. We are in the process of undertaking this task.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

12

SUSTAINABLE DEVELOPMENT AND QUALITY CERTIFICATION ISSUES : COMPETENCIES, KNOWLEDGE AND PARTICIPATION

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INTRODUCTION

Competitive success depends on the transformation of a company's key processes into strategic capacities that really provide superior value to customer (DRUCKER, 1992 [1] et STALK 1992 [2]). The last technical and economical evolutions renew the industrial systems' efficiency conditions. The search for «new production rationalization» (DE TERSSAC et DUBOIS 1992 [3]) shows the will to find new consistency between technical, economical and social spheres. As stated in sociotechnical paradigm : an open system adjusts itself while learning new informations. It enables actors to find equilibrium between human and technical needs (LIU 1983 [4]). New information technologies are part of this process. They claim for new organizational modes and ways of working together.

Sustainable development may be seen as a response beyond others, to these stakes : this concept meets several definitions and dimensions : ecology, health, social impact of technology development, ethics, politics, management, fair trade, etc. If sustainable development is "the management of the human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining the potential to meet the needs and aspirations of future generations." as G.H. Bruntland [1987] states it, the issues at stake here are multiple.

The Rio Summit identified *"Sustainable Developmen's Three Pillars"*:

◊ Social progress

Equity, Social cohesion, Social mobility, Participation, Cultural identity;

◊ Economic growth

Growth, Efficiency, Stability;

◊ Environmental protection

Healthy environment for humans, Rational use of renewable natural resources, Conservation of non-renewable natural resources, Participation, Cultural identity.

Many companies seem to assimilate environmental protection to sustainable development. They sometimes integrate these constraints from the product conception ("eco conception"). They usually don't really take into account social progress or ethics. Those questions seem to arise when huge efforts have been made to create an environmental management system. Managers then realise that they just began to think about environmental impacts. They discover the tremendous amount of work needed to be able to keep up with their own requirements, and even more if they want to go further.

We intend to explore how some French enterprises define and apply sustainable development policies to their own activities. We stand from a sociological point of view to show beyond the technical aspects many organizational and human issues.

Environmental labeling programs and environmental certification schemes are tools that have been used to promote sustainable development within industry. They are voluntary programs, even if a growing pressure may explain the fact that more and more companies decide to step in. They often choose to get the Iso 14001 certification to prove that they do create sustainable development.

These certifications assess the global environmental policy and management of a company. The aim is to give information about process and production methods, that is the environmental impacts of the company's resource use, production techniques, emissions, etc... They don't intend to assess whether the company is creating sustainable development; neither if it does reduce its pollution. They might give a target to reach, but as programs are voluntary, there is no obligation to do more than what government's environmental protection policies request.

If certifications can be part of the necessary conditions to really produce sustainable development, one may doubt that they are sufficient. Some companies, as we will show, can improve their action to contribute to sustainable development without certifications.

We carried a six months survey within seven French companies, including participative observation and managers' interviews. We picked enterprises interested in sustainable development, which officially claimed they were advancing in this field. Some were already iso 14001 certified, others not, but willing, and others chose a different approach.

This study focused on two main objectives : understand how sustainable development was handled within those enterprises and explore how the organizational structure and power relationships evolved to meet sustainable development requirements.

What are the main topics handled by the French managers we met, those fields which are therefore defined as top priorities ? Is there a global overview and knowledge about the firms production techniques and of their environmental impacts ? What are the main motives to adopt a sustainable development policy within companies ? What are the main stumbling blocks, are stakeholders easily motivated and participative in a sustainable development policy ?

We'll show how these issues require to study the way company create and diffuse knowledge, build new competencies and try to develop empowerment or at least local responsibility under certain conditions. As quality certifications are seen as organizational techniques, the company's global managerial system is rarely reviewed or changed. CEO's often decide to add a new department to their existing structure, as if promoting sustainable development did not need to change internal power relationships.

First we will wonder if an Iso 14 001 certified company would be more willing to make progress in sustainable development than one which is not. Then we'll explore a systemic approach of sustainable development. The role of management and coordination will be highlighted. Finally the results are discussed in the last section.

IS CERTIFICATION A PROOF OF A COMPANY'S WILL TO CREATE SUSTAINABLE DEVELOPMENT?

What's the iso 14001 certification ?

The Iso 14001 certification is a management tool which helps companies to track, understand and sometimes reduce their environmental impacts. There are no specific production procedures or methods to adopt. Companies that voluntary certifies to this standard simply have to demonstrate that they are aware of their environmental impact, are trying to control them, step by step, are monitoring the progress toward their targets and maintain continual improvement. Companies set their own environmental targets, and certification does not require an independent assessment of the sufficiency of these self set targets.

There is another standard : the Environmental Audit and Management Scheme. This one is less frequently adopted in France. We won't pay attention to the certification impacts on market access. What drove our study is to find out whether those certifications would or not modify deeply the organizational structure or production methods or culture, in a way that favours sustainable development.

Our definition of sustainable development

Gone to this point of the discussion, one might wonder what is our definition of sustainable development. This covers three different fields :

- Economic dimension;
- Environmental dimension;
- Social and ethical dimension.

The economic dimension concerns an organization's impacts on the economic circumstances of its stakeholders and on economic systems at all levels.

The environmental dimension relates to an organization's impacts on living and non-living natural systems. This dimension is widely agreed within companies.

The social dimension regards to an organization's impacts on the social system, which it operates, at local, regional, national and global levels.

Those dimensions are linked. Finally for us, **sustainable development concerns all possible impacts, visible and invisible, due to manufacturing or any other activity linked to an organization's existence**. It leads to a better natural and human resources management, by enhancing organizational' strategy global consistency.

During our interviews we explored four aspects of this new management:

I. Spare natural resources (energy and raw materials), thanks to environmental management systems, or to integration of these criteria from the product conception;
II. Empower employees and give them opportunity to participate to environmental policy, work organization, living standards, health and safety …
III. Increase open relationships between companies and their area;
IV. Respect and diffuse ethical principles, especially with its subcontractors and partners.

As one may doubt as to the industrial world' capacity to quit its old habits: short term benefits and costs reduction for example… One might consider sustainable development as a future competitive advantage, but actually, it is more likely an investment. We have then decided to explore the motivation for this new strategy.

During our interviews, we asked:

1. What was the main motivation for sustainable development;
2. Who took the decision to step in;
3. If some partners or competitors had already started and./or asked the company to move on.

What certification can cover up?

Managers we met said their companies' main objectives while creating an environmental management system were mainly to (by decreasing order) limit product's environmental impacts during its life cycle, reduce disagreements like noise, odour, rejects, pollution, to avoid spoiling, to give a good picture to the company, to motivate people.

One understands at once that the time is pragmatic. Most of the companies we've visited were not respecting legal pollution restrictions. Getting the Iso 14001 certification creates the opportunity to settle those prevailing and recurrent disorders. We are far from really protecting our future generations resources.

One may wonder what brought the idea of sustainable development. It's always the CEO's which decide to promote this process. There is sometimes a real care for environment. More often, a client make it compulsory for its suppliers. Competitors or partners may play the role of "opinion leader" (Lewin, 1947). Finally, gaining new points on international markets is also an incentive.

Lots of environmental protection service managers were proud to show that their colleagues truly picked their wastes. This might prove a day-to-day involvement, but at a very simple level. This involvement is very difficult to get. In fact, solving technical questions might be difficult, but the human challenge is more complex.

The Iso 140001 certification intends to develop as well social stakes, security, communication and training. There is a lot of work to do, simply to be in conformity with the laws. Then the certification may help to make a global assessment of the firm's existing system and capacity to prevent any environmental risks. This norm's benefits for the firm are multiple : it may develop a continuous improvement culture, give credibility and reliability, enhance the company's reputation and fame.

This management tool helps companies to track, understand and sometimes reduce their environmental impacts. It implies financial and human investments to understand and apply the quality procedures requested. The global tendency within the companies we've visited is to focus first on the technical aspects. When they get the certification the problem they face is to keep up. Those certifications are not living systems as long as people have to be fully dedicated to maintain the quality process. If those people disappear, sustainable development won't remain a priority.

A perverse effects appears when lots of energy is focused on technical aspects only, to the detriment of systemic and human factors.

SUSTAINABLE DEVELOPMENT IMPLIES A SYSTEMIC APPROACH

Those who get an Iso 14001 certification are not always the more willing to create and assess a fair and sustainable production In the firms were no certifications were chosen, managers were more likely to consider sustainable development as one part of their everyday responsibilities, even if they have had to change some organizational routines.

Immaterial assets

Sustainable development implies more than environmental respect. It requires a systemic approach including competencies improvement, regular appraisals, knowledge management, communities of practices, information and innovation strategies. Lots of researchers insist on the CEO's involvement to initiate the process.

One may not focus on the wrong objective: maintain one's certification and lose the global target: reduce the firm's negative impacts on environment, economic and social dimensions. It starts within the firm with communication, transparency, training and participation.

Furthermore, it focuses on quality and immaterial aspects of work organization as well as on social links. Organizational structures and power relationships provide good clues to understand what is the CEO's aim. But they are not sufficient to analyse the change process going on.

In French companies, one or more managers are dedicated to environmental policy. He is always executive and according to the firm, reports to the CEO's, the quality department or the production team. We found out that there were mainly two hypotheses. In the first one, the environmental manager reports to the CEO's. He's a kind of coordinator. He might lack for legitimacy and direct link with the plant. He is a traveller, and the risk is high to be enable to create a sustainable system. The second hypothesis consists on a manager dedicated to environmental protection, which belongs to the plant. In this case he will easily know if procedures are correctly respected by operators and be able to adapt and motivate the plant. The limits of this organizational choice come from the close link within local activity, which may prevent from a global approach.

The best solution at this time seems to adopt both solutions in a transversal organization.

Good wills are not enough

Environmental management is not settled once for all. Targets and objective become more and more difficult to reach. This system lives and grows as an open system. Good wills are not enough: recycle paper can be more pollutant than buying new one. There are no obvious facts. The recycling procedures are not always satisfactory.

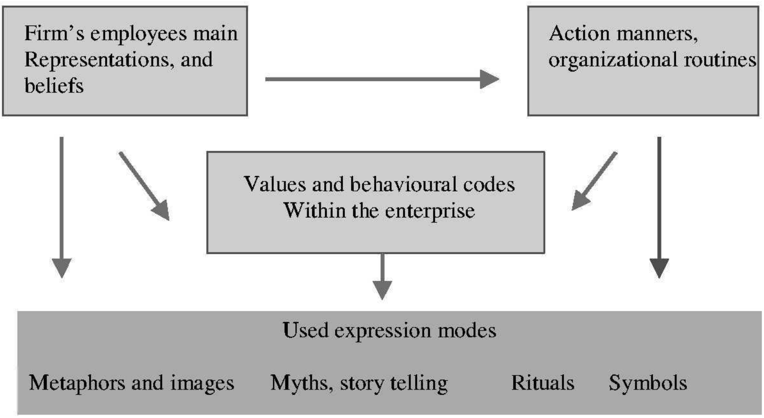
Companies managers won't get ride of those issues simply by spending money to reprocess their emissions. The most simple and efficient method remains to reduce energy, water, and raw materials consumption. Prevent using dangerous products; find other ways to add value. Furthermore there is no perfectly agreed resources consumption quantification procedure. Criteria are the firm's choice.

What seems to make a difference is employees day to day involvement. This leads us to the idea that the company's culture and values should evolve to integrate new behaviours.

Organizational change and culture are main factors

Considering the socio-technical system, we discovered the main importance of culture (Schein, 1996, Argyris 1995).It embodies values and inner rules into dominant and accepted behaviours, as our model summarize it.

Figure 1 Culture main components.



If sustainable development or quality certification are understood as organizational change, they will have an impact both on organizational structure and on culture. Due to regular assessments and audits, the whole system will have to adjust itself and learn form these new experiences. To make sense, the firm managers need to tale a story : our origins myths but also our children's life tale. Quality certification is a very restricting and boredom process when it runs. We have then to seek inner motivation through values and ideals such as our children's rights to inherit a pleasant environment.

Security, quality and environmental policies can't be imposed. Employees' participation is central. As soon as possible, people should be involved in the definition of the main priorities. Helping create a situation where systems can be self designing and support intelligent evolution seems to be the unique solution. It involves the creation of new shared systems of meaning that are accepted, internalised and acted at all level. This might appear in group work. It would spare time and energy to convince people : they would discover it while getting certifications or modifying the production process for instance. Therefore participation and self organization should be quality certification's basics.

DISCUSSION

Our survey is modest. One can't affirm that our results are valid for any company in any activity in France. Still we studied an electricity producer, two car manufacturers, a painting producer, a metallurgical industry, a water producer, a telecommunication unit. Several activities and some small enterprises as well as international companies are present.

The main limit of our work remains the difficulty to interviews also employees on the front line. This shall be the next step, to get a better picture of all the firms components.

Learning opportunities

Allowing every team member to embrace wider responsibilities and to learn from each other, the process become learning and mind opening centre. The challenge lay in the coordination of the skills useful to achieve a project, avoiding a hierarchical power structure, so that a real dialogue can begin between managers and « basic employees». A winner / winner logic can provide an efficient dialogue frame.

Participation is not only a nice idea. It provides useful barriers against major inconsistencies. By taking into account the actor's culture, representation and skills, it avoids unrealistic plans, failure to understand the stake in « real working life », impossible to know without being implicated in everyday work and practices. Participative management can also avoid the top down approach bias: actors won't feel forced in a change they were not informed of, don't understand the meaning and don't see the advantages nor the difficulties to find a solution (or why this solution was chosen). A project is more likely to be implemented with success if the solution fits its context while respecting global values like equity and justice amongst every salaried employee of the company.

Empowerment

Argyris showed to what extent empowerment can be misunderstood (Argyris, 1998). He clearly states that inner motivation is the only one nurturing organizational change and power decentralization. Another aspect that many team members highlight is the enrichment they gain mixing functional and operational skills and points of view. This is not so easy, a certain rivalry and mistrust at first could prevent them from working together. Their strategic interests can be different. Finally they usually manage as Revel (2003) points it, to work efficiently on common projects.

Real employees participation remains rare and comes at the end of the process in the firms we studied. Lots of CEO's lack for trust in people's awareness or rigor. They seem to believe that they need to centralize decisions. Given that context empowerment remains a concept. Managers speak about empowerment when they meet reluctance and inertia. Although it should be part of the process beginnings.

CONCLUSION

Those who get an Iso 14001 certification are not always the more willing to create and assess a fair and sustainable production. Organizational, social and economical factors are here at stake. Sustainable development implies more than environmental respect. It requires a systemic approach including competencies improvement, regular appraisals, knowledge management, communities of practices, information and innovation strategies. Furthermore, it focuses on quality and immaterial aspects of work organization as well as on social links. Organizational structures and power relationships provide good clues to understand what is the CEO's aim. But they are not sufficient to analyse the change process going on.

Observation and interviews of different stakeholders are necessary to assess the sustainable development policies. When the firm keep on thinking its existence as an independent system, the way may be long before the world "partners" appear.

Besides, will for sustainable development cannot be restricted to quality certifications. It requires also from every citizen and consumer a reflexion. Is a product or service social utility compared to its environmental, social and economic costs still essential? Is success a mater of possession, wealth, and comfort or of self-enjoyment and being? Our answers will certainly contribute to sustainable trends.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

13

A PROPOSAL FOR CONSIDERING SUSTAINABLE DEVELOPMENT AS A TOOL FOR COMPANIES TO EVALUATE THEIR FUTURE DEVELOPMENT SCENARIOS

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INTRODUCTION

The leaders of the world admitted, at the first Earth Summit in Rio, and reaffirmed until the recent Johannesburg Summit, that "the principal cause of continuous degradation of the world environment is a model of consumption and nonviable production, in particular in the industrialized countries, which is extremely alarming because it worsens poverty and creates imbalances".

Companies are the first concerned, whether they be leaders or followers, multinationals or SMEs. We know about innovation which relates to a product, a process or a new activity; but can one speak about innovation when the added value is not measured against the result (what the firm or the organisation produces for its customers) but on the way in which this result is obtained (human resources) and how this difference impacts or can impact consumers? The representation of value will differ from one person to another and above all the intrinsic value of a product is related to personal values which are constantly evolving. This subject is widely synthesised by the sustainable development concept.

Beyond the context which highlights the contradictions of our societies, which companies submit to or resolve, the example of sustainable development describes how a concept can stem from values that are not shared and yet be integrated by companies in order to gain an opportunity of equitable development for everybody.

So, we show that sustainable development can be considered as a tool to evaluate economic scenarios: it can provide a competitive advantage by developing both products or technologies respecting the environment and society's values throughout their life cycle.

Finally, sustainable development could be integrated into social development scenarios where companies listen to all those involved in projects (internal or external) and to their values.

I - THE CONCEPT OF SUSTAINABLE DEVELOPMENT : TOWARDS A SUPPRESSION OF CONTRADICTIONS?

I.1 - ORIGIN OF SUSTAINABLE DEVELOPMENT

The concept of development sustainable has been gradually developed since the Seventies with the discovery of the limits of the means of growth of our companies that are exhausting natural resources and generating a great disparity of wealth. With the cry "we have only one Earth!" (Stockholm-1972) various currents of thoughts came together. It became necessary to protect the environment against the degradation of ecosystems and against the exhaustion of natural resources related to human activities. Then, gradually, a socio-economic dimension was added to the environmental dimension. The expression "sustainable development" was invented in 1980 by an ecologist NGO, the IUCN, in its "world Strategy for environmental protection". The World Commission on the Environment and Development (UNO) uses the term and states, in 1987, in its report "Our future" called the "Brundtland Report" (the name of Madam the Norwegian Prime Minister who chaired the Commission) the need for adopting sustainable growth.

In 1992, 173 States committed themselves towards sustainable development by underwriting "the Rio declaration on the Environment and Development" and a document of more than 2500 proposals for actions "the Agenda for the 21st century" (commonly called Agenda21 or Actions21)(CNUED, 1989).

The collaborators of companies who work in those fields close to the criteria observed by sustainable development each have their own definition of the concept. These definitions are at the very least very disparate and confusions are often made with the concept of ethics or ecological voluntarism for example. It is enough to tackle the subject in companies, to evoke the social responsibility of the company, to begin a discussion about ethics and moral values. In fact, it is not what we mean when we speak about sustainable development.

Beyond the company, Crabbé (1997) recalls that no definition of sustainable development unites the voices of philosophers, ecologists, economists, sociologists, politologists and others.

I.2 - AN ATTEMPT AT A DEFINITION

I.2.1 - Semantic clarification of this new concept

Development does not only include the economic vocation of the company but also covers the objectives and the more individual intentions with all of its partners in a long-term vision by committing to the responsibility of all. The debate of the primacy of one objective over another, economic objective or social objective, has become sterile. Companies have to be involved in a process that combines both requirements.

The concept of temporality is included in the word sustainable that indicates, as an essential principle of the development of companies, the long-term vision of the commitments entered into. It also covers the dimension of support and assistance (bearable, acceptable, viable development). Thus, it invites companies to register the range of their management decisions over a longer time scale and to guarantee a certain stability.

Whereas there are publications on all of the various concepts related to sustainable development, the subject has never yet been covered as a whole. There are many surveys that approach human management, the impact of companies on the environment, quality and relations with customers and suppliers as well as the principles of the healthy company government, or the deontology of companies. But it is also the total harmony of the various missions of the company and all of its relations with its various partners that it is necessary to study and know to apprehend. An overall way is thus complex.

The emergence of the concept is not recent in the United States and in some countries of Northern Europe that saw, by the means of investment funds in particular, certain militant minorities introduce ethical and ecological concepts alongside purely economic and financial considerations. Very early, in these countries, observation of companies was made with other frames of reference than those of simple profitability. Through the various criteria it integrates, sustainable development takes into account the cultural bases involved. Thus, within companies, the place of workers and social orientations are dependent on the cultural, political and sociological values in force in the country or in the geographical area where these companies are based. It's also right for all the other criteria of the concept. It is the cultural background that gives " colour" to the various criteria of sustainable development in each country.

Similarly, the influence of the business sector of the company must be taken into account in the various criteria of sustainable development.

Today several factors make sustainable development, a "fashionable" concept. The media focus on certain events (ecological problems, but also certain social dramas) has favoured this awakening of the need for a new orientation of business development. The globalisation of economies and exchanges, favours new models of regulation, more complex and global than the simple domination of money. The conference of Porto Alegre in Brazil stigmatised the limits of models of exchanges built on the principles of profitability. This conference, which competed with the conference of Davos in Switzerland, did not refute globalisation as such, but underlined the importance of social data in the rules of these exchanges.

I.2.2 - A complex concept

Sometimes, the concept covers fields with contradictory purposes. In its broadest meaning, the sustainable development of the companies is analysed through a significant number of not easily measurable and quantifiable criteria that one can classify according to the following fields:

social action (individual and collective), environmental management, corporate governance, external contractual relations of the company (customers and suppliers), relations with the sporting and cultural civil society, actions of insertion, deontology and humanitarian actions and human rights.

It is sometimes difficult to make the interests of all partners compatible. For example, how can we combine the interests of workers with those of organisations for environmental protection when we have to give up an industrial activity, certainly employment creating, but with polluting consequences?

Lastly, the concept is complex, but also relative, i.e. it varies according to countries and companies. But certain fundamental values transcend sociocultural differences and the essential elements would have to articulate around long term considerations which would preserve the environment, which would take into account the balancing of the interests of the various players of the civil society, and which would place at the centre of corporate management the customer whoever that might be (Férone et al, 2002).

I.2.3 - A definition that will evolve with time

Sustainable development that is not paradoxical with the concept of economic progress and financial profitability can supplement the operations of a company by guaranteeing performance in the long term.

It appears difficult to give a definition of the concept of sustainable development that is universal. By nature, it is evolutionary in time and space. The difficulty is thus significant for the major international firms that wish to apply transverse modes of management, and find directly operational principles.

The most recognised definition by the international community is one resulting from the Brundtland report: " sustainable development is a development which meets the needs for the present without compromising the capacity of the future generations to meet theirs." (CNUED, 1989)

By "needs", the report understands fundamental needs, such as food, employment, energy, water and hygiene. The Brundtland Commission was less interested in the definition of an ecological objective than by the achievement of socio-economic objectives such as the access to resources and the equitable distribution of the costs and the advantages of development. It wished to see the human population stabilised on a level suitable with the productivity of ecosystems. It also wished to see economic growth starting again in the industrialised countries and the developing countries. That leads to the following fundamental question: does one seek, with sustainable development, to have everything, in other words to have a high growth rate and to protect the environment at the same time? (Lélé, 1991).

In fact, one can define sustainable development as the search for a dynamic balance between three dimensions: environmental protection, social equity, and economic effectiveness. The aim is to bind the three spheres, to seek a balance by adopting a triple gain strategy from economic, social and environmental points of view by integrating these three dimensions in any project or any action (Figure 1).

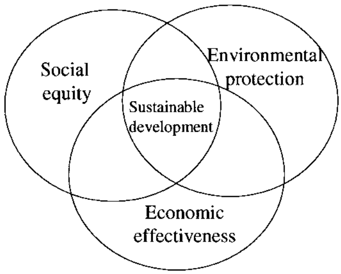

Figure 1 : the 3 spheres of sustainable development

I.3 - CONCEPT OF SUSTAINABLE DEVELOPMENT: THEORETICAL BASES

I.3.1 - Economic approach to sustainable development

Sustainable development is distinguished from the environmental economy (which, compared to the economy alone, aims to integrate external factors) in that the latter is only one chapter of the neo-classical economy, while sustainable development calls into question the very utilitarian ethical principles of the neo-classic economy. The function of timeless well being in sustainable development, if it exists, differs from the function of neo-classical timeless well being which leads to the maximisation of discounted value. However, in the very long term, the latter is incompatible with the sustainable development. The maximisation of discounted value does not take account of questions of equity, whereas sustainable development relates primarily to intergenerational equity.

Sustainable development can be regarded as a political ideology or a Utopia. As an ideology or a Utopia, sustainable development competes with other ideologies such as the ideology of the open market. Ideologies are synthetic and systemic beliefs intended to mobilise people so that they act. They are not scientific theories but rather scientific residues of theories (Dumont, 1974). In this context the intervention of authorities plays a significant role in sustainable development. Voluntary actions are not enough to implement a political ideology. "The challenge for governments and environmentalists is to find means of creating the incentives which will convince industry it is profitable to be clean." (Cairncross, 1991)

The elements of sustainable development have already been the focus of rigorous economic analysis, but there is no detailed economic theory of sustainable development that goes beyond economic problems (Crabbé, 1997). For example, the fact that nothing in the neo-classic economy is proposed to define the conditions to guarantee a durable economic optimum shows that economic theory does not include viability (maintenance of the value of capital, an essential element of intergenerational solidarity) as it should (Pearce et al, 1990).

I.3.2 - Principal characteristics of sustainable development

(a) Development must be sustainable. Development does not only mean economic development. It also includes social and cultural development (Pearce et al, 1990). Although external factors (air, the "quality of life", well being, happiness, authenticity, spirituality, beauty, sacrifice, etc, all things which concern ethics, culture and religion) are obviously excluded from GNP because they are not negotiable, an internalisation is necessary but not sufficient to exceed the distinction between growth and development.

According to the endogenous theory of growth, technical progress and human capital, which were hitherto (in the Eighties) like a measurable but exogenous residue, become variables of growth on which one could act. It is on this idea of positive externalities of these factors of production that Porter (Porter, 1986) built a new formalisation of the determinants of economic growth (additional factors not entering within the framework of the GDP, but lying rather within the broader scope of the Total Productivity of Factors (PTF)). It is about the endogenous model of growth. Thus, according to this theoretical framework, economic policies in favour of education (human capital) or innovation have a real impact on the sustainable economic development of companies and nations. On the contrary, it is a question of taking into account "negative" external factors when one speaks about pollution for example (Daly et al, 1994).

Thus, if one represents sustainable development by sustainable growth (Férone et al, 2002), then the endogenous factors such as human capital and the safeguarding of the natural environment are real engines for a sustainable development of companies and nations.

(b) The socio-ecological system is a closed system, whereas the economic system is an open system (Rosnay, 1977). The economic system is an open system compared to its physical environment. Thus the economic concept of the closed circuit model became invalidated. There is always an interpenetration of the economic system and the environment.

(c) The complementarities of natural capital and other factors of production. Natural capital is the source of services (ecological functions and the world's natural resources) and of the environmental pit (physical waste). To not recognise the complementarities between natural capital and production factors could inevitably lead to the degradation of the environment or a weakening of development potential or a combination of the two phenomena.

(d) Intergenerational, spatial and intragenerational equity. An interpretation of intergenerational equity requires that the well being (general utility) of all generations should not decline in an unspecified future. Intragenerational equity means simply the death of poverty (the World Bank, 1992). To take account of this double dimension of durability, temporal and space, the concept of widened sustainable development is introduced.

(e) The decentralisation of socio-ecological decisions. Governmental institutions, with their vertical mandates, are perceived as being unable to manage sustainable development, which requires horizontal mandates. Moreover one political principle called "the principle of subsidiarity" recognises various stages of decision-making, the higher stage helping the lower stage, and not the opposite (Daly et al, 1994).

(f) To apply the principles of prudence and irreversibility to socio-ecological decisions (principle of precaution). The principle of prudence calls for policies that avoid risks, because of our dubious knowledge of the environment. The principle of irreversibility takes into account the value of future learning possibilities based on the fact that no irreversible decision has yet been made, except that of avoiding risks (Pearce et al, 1990). In practice, this means that the cost-benefit ratio is not a sufficient criterion to make irreversible decisions, except if the costs include/understand the value of future information which one gives up by making an irreversible decision and which could make the decision taken regrettable (Crabbé, 1997).

II - HYPOTHESIS OF A MODEL OF INTEGRATION, PREMISE OF A TOOL TO BE TESTED FOR SOCIETAL FORECASTING?

II.1 - SPHERES OF INTERESTS

The concept of sustainable development can be summarized with the long-term convergence of interests which may appear, a priori, contradictory. To be responsible supposes accepting and being subject to the consequences of one's acts, and also agreeing to respond. In the theory of the fascinating parts, the company is supposed to go in the direction of a general social consensus (if this option is in conformity with its interest). The taking into account of the fascinating parts is one of the ways to reach consensus outside of clear and feared constraints, but responds to various pressures.

Firstly the pressure of socially responsible funds is increasing without a formal link having been identified between socially responsible behaviour and better stock exchange performance. The absence of counter-performance makes the case for its development and tends to institutionalise what yesterday seemed alternative and radical.

Secondly, the pressure of public opinion is increasingly mounting. There are many examples to illustrate the concerns or the doubts expressed regarding problems of pollution, public health or food hygiene, by a hybrid but impossible to circumvent being, made up of a new "alloy" that would be at the same time parent, citizen, taxpayer, resident, consumer, employee, trade unionist and shareholder. The univocal communication of a company directed towards the exclusive attention of the institutional shareholder appears insufficient and sometimes truncated or dishonest.

Thirdly, the company cannot, without exposing itself to serious risks, function in the realm of refusal, opacity, contempt and incompetence, arguing against the inadmissibility of questions and new modes of evaluation, seemingly distant from its function of uncontested utility: to generate profit. Companies, on the contrary, in a social and natural environment that is in constant change, will have to demonstrate porosity in order to anticipate understanding of the complex balance of power impacting directly on its activities (moral pressure).

II.2 - INCUBATION OR INTEGRATION

The example of sustainable development clearly shows that the challenge is to find grounds of agreement between players with contradictory interests but who, despite everything, coexist.

How can grounds for agreement be found? Several observations can be made on this subject.

- the temporal dimension is given by possible evolution of the model which operates through the possible movement of the players from one sphere to the other.
- the choice of the players operates by the choice of contradictions that are accepted and not the opposite.

The objective is to adopt a simple mode of representation (fig.1), in order to predict, to a certain extent, the evolution of the system that requires knowing the players in each sphere and their relationships and having a photograph (measurements, indicators) that clearly defines the problems (contradictions) to solve. The political process must solve the " limited conflicts " between people whose values differ and are sometimes opposed. The political process is initiated by the Government: it can thus, for example, inflate its importance to widen the intersection of the spheres or launch educational programs and research for companies and individuals the divided by the same values. It is each time a question of shifting the balance of the system.

II.3 - SHIFTING THE BALANCE OF THE SYSTEM

Understanding the finite nature of the planet and the Biosphere combined with the uncertain economic challenge regarding the equitable division of the promises of science, technologies and development, for a human population in full demographic explosion, leaves the door open to reflection on the indeterminism of human evolution.

The theorem of Gödel (known under the name of the theorem of incompleteness) of the undecidability of open systems (mathematical theorem which applies to cybernetics) makes it possible to understand better what transforms a deterministic system into an indeterminist system (Rosnay, 1977). This open breach of uncertainty makes it possible to formulate assumptions of forecasting suitable for renewing the contents of reflections and debates on sustainable development. Here we propose three potential assumptions :

- the first one takes note of a final historical victory on a worldwide scale of market forces (pre-eminence of the business sphere): the exchanges between humans are controlled and dominated by the presence of only one reference mark, money, which has become a finality. With globalisation, world governance is ensured by multinationals which are ever more concentrated and which already, before the year 2000, monopolized a quarter of measurable economic activity employing only 61 million people on the planet (UNO figures): for the first time in History, "the rich no longer need to exploit the poor",

- the second scenario (or assumption): a Marshal plan for education and sustainable development. Pushed by world opinion increasingly conscious of the danger of capitalism without faith or law, of a civil society which makes its dissatisfaction and its distress heard, Politics returns to the international scene: the application of morals (ethics) revisited and shared by society. This second assumption can find its marks in a reinforced alliance between the community of "scientific experts" and large industrial firms, closely and culturally bound, under the banner of a Marshall plan for the South. This scenario renews links between public interests (States bypassed by globalisation) and private interests (multinationals) under a media focus on humanism and peace. Escaping to technology (industrial sensors and satellites, purifiers, biotechnology and genetic engineering, micro-electronics for monitoring and control, biomaterials etc.) becomes a pretext for saving the planet and growth. The logic of the market, individualism, and the new technical system, are combined together as in the past, but with the multiplication of codes, standards, rules, suspicions, labels, controls and monitoring.

These first two scenarios, that can follow each other in time while still overlapping, have the characteristic of falling under the continuity of a "determinism" of development already quite observable at the present. They are both faithful to this vision where meaning (truth) is external data, transcending and independent of human conscience.

- In the third scenario (or assumption), it is not in poverty but in wealth that the problem of poverty resides. In this current of thought, there is an understanding there that the majority of Northern countries stamp an ecological imprint on the World of taking away much vaster resources than their territory possesses for the population which lives there. An understanding too that what is taken away by world growth from the Biosphere adds up, every two years, to that taken away by Humanity until 1900! By refusing to separate the ecological crisis and the social crisis, those that hold this third assumption do not dispute the implementation of a "revolution of efficiency": to produce better with less taking away and less emissions, such as those of the second scenario of scientific ecology propose. Their criticism focuses more on the way in which this revolution of efficiency can be used to justify the blind pursuit of growth and its counter-productivities. The alternative to this revolution of efficiency programmed on a planetary scale lies less in the sophistication of techniques than in another rationality to be found within shortened chains of production-consumption. That is to say less intermediaries and transport, less active participation in long exchange circuits, on concrete life spaces of exchanges and decisions reduced to the level of the territories to which one initially feels oneself to belong. Finally, this third scenario is characterised by the conviction that a revolution of efficiency will have effect only when associated to another more intimate revolution on the scale of the individual: a revolution of sufficiency. The revolution of efficiency does not know where it is going, if it is not accompanied by a revolution of sufficiency (voluntary restraint) registered in an ethic of everyday life.

These three scenarios are only pure socio-economic and political forecasting, but show the existing place for a possible societal forecasting. Forecasting based on a model that has to be developed and validated, and which companies would do well to appropriate to have future competitive benefits. Indeed technological innovation being par excellence the science of linking, it could arise tomorrow from questions on the evolution of the links between the values held by the different stakeholders.

III - MODES OF APPLICATIONS TO COMPANIES

III.1 - OVERVIEW OF THE TECHNOLOGICAL FORECASTING CONCEPT

III.1.1 - Historic view of the concept

Even though the definition of forecasting was given in 1957 by Gaston Berger, the development of the concept came in the 70's. Indeed, the frequent errors of forecasting and particularly the lack of predicting the crisis, lead to a serious examination of the foresight approach. The impossibility to foresee the future only with data coming from the past explains the limits of classical econometric models. The latter do not integrate non quantitative parameters such as individual behaviour in a project. More precisely, the specificity of the forecasting concept comes from its temporal dimension, its field of application and its objectives (Godet, 1977) :

- temporal dimension : foresight is used in short or medium term considerations because it needs a strong stability of the external parameters of the system under study. Conversely, the forecasting concept deals with a long-term perspective and so can take into account changing environments and evolution in the associated parameters.
- application field : foresight must precisely define its field of intervention in order to increase its degree of pertinence (fragmented vision). Whereas forecasting takes into account the interrelations within the different fields (global and systemic vision).
- objectives : By definition, foresight tries to see in the past what will occur in the future. Indeed, most of the foresight methods are based on an extrapolation of trends in a short-term view to reduce the risks of errors. Forecasting has another objective. It tries to classify better and to understand better the key elements of the present situation. It gives more importance to knowledge of the mechanisms and the means that lead to the most desirable future. The time scale is usually between 10-15 years.

III.1.2 - Principle of technological forecasting

Seven assumptions are used as a basis for technological forecasting (Godet,1985).

1. Design tasks should be considered with a view towards the future; the relevance of a scientific choice in a technical decision depends partly on an analysis of the possible future and the consequences of the decision on this probable future.

2. The future is multiple and uncertain. We can only talk about multiple evolution scenarios. Furthermore, there are breaks between the past and the future: the emergence or questioning of some basic concepts.

3. The approach must be systemic and global. As evolution accelerates, interdependence is increased, everything affects everything else.

4. We need to talk about qualitative and quantitative variables.

5. Pluralism and the complementary type of methods increase efficiency. This "methodological wisdom" is justified in the complexity of the phenomena.

6. Information and forecasting are not neutral. The research worker influences the object that he or she is studying.

7. Maximum questioning of accepted ideas. Technological forecasting cannot be reduced to a simple extrapolation of current trends. These seven assumptions are fundamental for technological forecasting and highlight that a systemic approach is the basic framework for any forecasting purpose. Thus, purely statistical methods cannot be developed since analysis by averages can only take account of accepted opinions. Furthermore participative methods are necessary to process various types of information. The tools used take account of these principles.

III.1.3 - Technological forecasting tools

Different tools have been produced for the use of technological forecasting approaches. They are always built using a scenario type approach that consists of:

- analysing the studied phenomenon: by listing internal variables,
- studying the environment of this phenomenon: by listing external variables,
- identifying key variables within this set,
- classifying key variables into driving variables (that influence the studied system) and dependent variables (that describe changes to the studied system).
- analysing evolutions of these variables in the past and germs of change, and possible new trends,
- formulating assumptions for the future form of these variables,
- consolidating these assumptions within complete evolution scenarios.

In order to complete this type of approach, we used two tools generated by Godet, namely the MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée au Classement - Cross- impact matrix multiplication applied to classification) structural analysis and the SMIC (Système et Matrice d' Impacts Croisés - System and Cross-impact matrix) method. MICMAC allows both the identification of internal and external variables and a better understanding of the interrelation existing between them. SMIC consists in a validation of possible evolutions of these variables thanks to an expert inquiry.

III.2 - WITHIN THE FRAMEWORK OF A SOCIETAL FORECASTING THROUGH THE CONCEPT OF SUSTAINABLE DEVELOPMENT

III.2.1 - Implementing practices in favour of environmental protection : on this assumption, companies would be brought to innovate to improve the environmental quality of their products or production process. This naturally generates additional costs for "green" products that are directly integrated in the selling price. But contradiction comes from the fact that, with equivalent prices, one will consume more green products if the environmental aspects worsened (Beaumais et al, 1994).

According to this outline, companies, leaders in the production of green products, will have a comparative advantage compared to the others, in terms of innovation and market share, which is materialized by an improvement of their economic and financial performance in the medium and long term. In addition, it is easier for a company to become green if it knows that the risk of a competitor adopting its more ecological production techniques is weak and if it knows that competition based on environmental criteria is practically non-existent (Cairncross, 1995). However, except for some companies occupying particular sectors, green consumerism will never be the motive for the environmental preoccupations of companies (Cairncross, 1995). Green consumerism relates only to a limited category of products because, among other things, it is very difficult for the consumer to evaluate the environmental effects of many products.

III.2.2 - Management Philosophy: from sustainable development to the socially responsible company : "Sometimes, a company needs to feel that its influence on the community is beneficial and not only motivated by profit" (Cairncross, 1995). Hard growth (in other words, physically increasing the production of goods) will be replaced by intelligent growth, in other words by an improvement of the quality of life thanks to the transformation of environmental constraints into possibilities. The design of systems (interactions) replaces linear design (cause-effect) and recognizes the holistic relation between the quality of the product, customer satisfaction, the positive image of the company and sales (Senge, 1990). Adaptive strategies which meet social, environmental, political and economic needs must be based on an ethical reasoning so that managers can determine who is concerned by decisions, how they are affected and what are the rights of the person in question.

Good management is applied at the strategic level and the operational level. One understands by responsibility that the company go beyond legal and contractual regulations and seek to conform to the current requirements of society: "whereas the concept of social requirement tends to proscribe, that of social responsibility tends to prescribe" (Smith, 1993).

III.2.3 - Competing strategies : Porter (Porter, 1986) identified three generic competing strategies. They are the strategy of lower cost (standardization of the design of environmental products, production systems designed in a closed loop by saving energy and resources and the use of clean technologies), the strategy of differentiation (environmental characteristics and packing of the product) and niche strategy (for ecological products) (Porter, 1986).

These ecological strategies make it possible for companies to gain advantage in market segments sensitive to environmental questions, as well as inimitable advantages in production. However, to obtain these advantages, organisational systems must be designed so as to be able to accept, treat and integrate the ecological signals emitted by the external environment. The size of the plant must be determined compared to its ecological impact (Sachs, 1997). Porter (Porter, 1986) affirms that the conflict between the environment and economic interests comes from a static vision of the world. This conflict no longer exists in a dynamic world founded on innovation. Environmental standards involve innovations whose advantages compensate for the cost of meeting the standard. Empirical data do not always corroborate this assumption known as Porter criteria (Jaffe et al, 1995).

III.2.4 - Respect of the principles of corporate governance: generally, the respect of the principles of corporate governance must improve the quality of the relationship between managers and shareholders. This will influence the emergence of good corporate strategic choices and the improvement of its long term performance.

III.2.5 - Which strategy: vertical or horizontal integration? : the traditional economic definition of an industry (group of companies which produces very similar replacement products) is slowly giving way to a systemic definition according to which one can call industry a group of companies which manufacture complementary products and which form part of a technological network of products. The environmental effects are related to the network. Technology is the "emergent" property of the system; it is a symbiosis of sources of materials and energy and models of consumption (Crabbé, 1997).

Environmental changes thus require systemic innovations. If one designs an electric car, for example, it is also necessary to conceive the context in which it will be used. Technological development goes beyond simple technology; the particular social background in which technology is to be applied will have also to change (Cramer et al, 1991). It can be necessary to control the assets. This supports vertical integration because of the complexity of contractual agreements founded on uncertainties, technological interdependence and information exchanges (Kemp, 1994). However, vertical integration is likely to slow down the rate of environmental innovation because the companies with vertical integration have made large technological investments both upstream and downstream.

Vertical or horizontal integration of industry can also affect viability through the creation of ecosystems or industrial networks integrated within natural ecosystems (eco-industrial area). These industrial ecosystems seek to create interdependent industrial networks modelled on biological ecosystems. Production installations can take each others waste, heat, water and other resources in order to reduce the total consumption of resources and the quantity of waste in the whole network. They use waste from an other company as raw material. The network is then used to handle waste rather than just the company itself and a collective effort is made to minimize waste and to save energy, raw materials and water (Bailly, 2002).

It will be necessary to adopt selective environmental strategies (Cramer et al, 1991). Ecological technologies will replace older technologies after a long period of experimentation in very diverse applications. The initiatives of the public sector and public investments are generally essential in the first stages of a new technological system, and interindustrial dissemination tends to follow a foreseeable course. In other words, the process of selection or the modification strategy does not depend on a menu presented by some innovators and offered to the "customers"; in fact, they depend much more on the initiatives of the "selectors" and the political process (Freeman, 1994).

The commercial prospects for ecological products also influence product innovation, and materials and energy saving influence the process side of innovations. Then, the most significant factor for process innovation is the internal pressure exerted by staff concerned by the environment. Environmental interest groups, the threats of demands for compensation and the pressures of responsible investment funds are perceived as negligible influences. The three organisational factors which influence innovation are collaboration with customers and suppliers, the need for investing in new factories and the need to devote more funds to training (Green et al, 1994).

III.3 - WITHIN THE FRAMEWORK OF SOCIETAL FORECASTING?

Forecasting is an exercise which consists in analysing how future technological options and various possible development trajectories could, in the medium and long term, draw advantage from social engagement (Chap III1). The example of sustainable development invites us to think possible a synthesis of technological forecasting (within the meaning of engineering sciences) with a social forecasting (with the aim of listening to all players). This synthesis could be called societal forecasting, a strategy which would actively imply all players (representatives of nongovernmental organisations, consumers, shareholders, etc without forgetting the experts of the industrial sector and government) possibly affected by:

- the definition of the objectives of the technological policy;

- the definition of the various trajectories of foreseeable technological development and their consequences (in particular their acceptance by society);

- the definition of a normative framework for this forecasting and the contribution to a more social orientation: we understand here by technological development (and policy) an active and constructive procedure aimed atdesired social and economic objectives (Todt, 1997).

- the same technology, according to the way in which it is developed, can have a very different reception by the general public. Forecasting in which all the social players would take part could bring new elements to guide choices at the time of decision-making. This work would provide, for each proposal, information which would reduce uncertainties as to the social, political, environmental and economic repercussions of each decision. Societal forecasting would also make it possible to guarantee the efficiency of public R&D programs by engaging industry in socially acceptable developments.

It would also allow industry to pay more attention to the specific applications of technologies. An exercise of public forecasting would thus offer a comprehensive framework to industry which could use this strategy to define the socially acceptable uses of a particular technology, as well as product lines. Of course, the commitment of the "stakeholders" would not replace current forecasting methodology, it would rather come to supplement it and to improve its effectiveness in particular cases. Is the field thus free for new challenges in research?

CONCLUSION

It is a hard task to work on values and also confront companies with their environment on the widest scale, but it is the most passionate because of its universal nature. Contrasts in the world show the need for imagining other modes of production and companies are the first concerned. Their role can be determining and will be so if they can put in synergy the skills they have at the service of "political innovation" with unquestionable repercussions in technological terms. Sustainable development is a beautiful example of an unclassifiable concept, born from the science of the link between various partners oriented toward the balance of the eco-system in all its dimensions. To believe current international rhetoric (see the conclusions of the Johannesburg Summit), we are already turning the page of sustainable development, even if it is intuitively judicious. It is making way for "sustainable social growth" for which the restrictive factor is no longer the environment but the "world heritage of knowledge". Human and social capital and the elimination of poverty have become the social infrastructure. The results are evaluated according to the "quality" of the infrastructure. The "Gospel" of efficiency prevails over the moral doctrines. Let us hope and act so that it is not to the detriment of a balance that the majority of the citizens of the world seem to seek?

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

14

UTILIZABLE INFORMATION SOURCES OF COMPETITIVE TECHNICAL INTELLIGENCE IN JAPAN: THE CASE OF ONE OF JAPANESE MEDICAL APPLIANCE COMPANIES

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INTRODUCTION

Customer Focused Technology Planning (CTTP) is one of the known competitive analysis methods to compare strategic products among competition with an aim to develop strategic products and technologies.

In this research, we examine the competition among a Japanese medical instrument manufacturer, its domestic competitive company and a foreign medical instrument manufacturer that has branched out in the Japanese market. The scope of the analysis ranges from the market of the domestic competitive company in which they operate, market profiling, customer needs analysis, technology impact analysis, CFTP map and patents of the three competitors in the highly competitive Japanese medical information monitoring system market.

CFTP map is effective in uncovering potential new product and technology opportunities among competition. This is especially true as it discloses relation between technical and market advantage in mature markets, CFTP makes good use of realistic and concrete strategic development methods. Comparing the result of CTFP and patent analysis is also of importance. We consider that if we can put weight on the patent analysis result to incorporate it into the CFTP map in one way or another, accuracy of the analysis can be improved.

THE OUTLINE OF CTI AND CFTP

Technology development has progressed past concept and feasibility assessment, and development has been initiated, but no commercial activity has yet begun. Patents are being field and issued. The focus of intelligence is on specific technologies under development by actual or potential competitors. Trends can be measured along with size of efforts. Patents are prime source of written information. Other key sources are internal and external gatekeepers, lead users, and strategic suppliers.

CFTP is a planning framework designed to help firms focus their technology investments in areas that will have a significant impact on their markets, their operations, and their shareholders. The concepts behind CFTP were developed over the last twenty five years in consulting assignments with many corporations around the world. CFTP is based on the model of innovation developed at MIT about 40 years ago. Innovation occurs when needs are coupled to the technologies that address those needs and the resulting new process, product and service ideas are developed in a responsible way that the risks and rewards of doing something new.

CFTP starts with the collection of information on:
(1) Your goals and capabilities

(2) Your customers' current and unarticulated needs
(3) The technologies potentially available to you and others to satisfy those needs, and
(4) The capabilities and intentions of your current and potential competitors.

A structure approach helps identify holds in what you know, provides a record of your assumptions, and focuses information gathering efforts.

THE FUNDAMENTAL CONDITION BETWEEN THREE COMPETITORS

In this report we analyze the competition between three companies, company F, company G, and company N from company F's perception. Company G and company N is headquartered in the United States and Japan respectively. The objective of the analysis is to formulate a new product and technology development strategy for company F to compete with the two companies. Company F still has competitive edge in the domestic market in connection with cardiograph equipment. The company F has won confidence from hospitals and doctors but is concerned about company N and G's launch into the market.

The analysis is a five-step process. Detail is as follows:

(1) The analysis of medical information system market in Japan
(2) Customer needs analysis
(3) Technology impact analysis
(4) CFTP map
(5) Patent analysis of the three companies

Despite its competitive advantage in the medical information monitoring system market, company F was seeing domestic company N as a threat to its business. The US-based firm company G's increasing market share was also a threat to the company.

STEP 1: THE MARKET SHARE OF MEDICAL INFORMATION MONITORING SYSTEM IN JAPAN

Predicted Value of Market scale is 230 hundred million yen (US $ 2 hundred million) in 2002. The average selling price of the product is likely to decrease. As the characteristic of medical information monitoring systems in Japan, developing the system based on cooperation between hospital information systems and nursing support systems. Promotion of integration activities by overseas makers has facilitated the emergence of one aggregate system including all medical instrumentation in one hospital, even by one company.

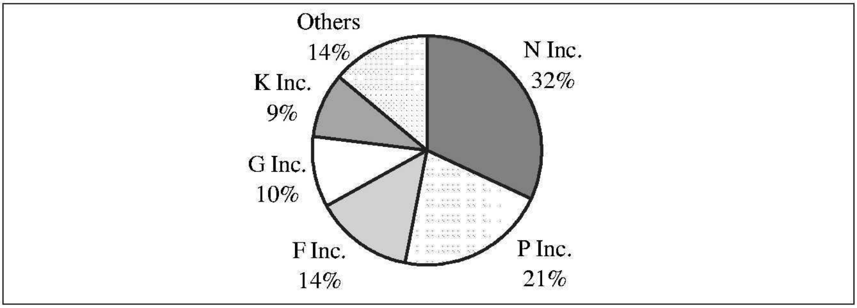

Figure 1 The Market share of medical information monitoring system in Japan

Figure 1 displays the market share of five major companies operating in the Japanese medical information monitoring system market. From figure 1, we can see that company F accounts for 14% of the total share. Also, company N's competitive position is evident from the chart. Rival company G dominates 10% of the market. Market share alone, company N shows competitive advantage.

STEP 2: ANALYSIS OF CUSTOMER NEEDS

This is one of major analysis of a technical group, particularly if you are isolated from the customer as is often the case. The following are some techniques to determine customer need:

Customers themselves are probably the best source of information on their needs. We have to look at potential customers. Specifically:

- Conduct customer visits. Be sure to plan this activity with the same rigor as other parts of a product or technology development project. Before the visit, prepare and know what you need to know, who will collect it, and how. On the visit talk, listen, and observe. After the visit conduct a debriefing of all those involved to ensure that critical information is not lost.
- Involve customers in planning, design and /or development.
- Identify lead user – supplicated users who have adapted your product or service to their needs.
- Conducting market research using your own sales force, marketing department, outside consultants, commercial database and on-line services, etc.
- Conduct problems research; i.e., look at their current operations and assess whether there are ways you could help them do what they do now but do so better, faster, or cheaper.

For consumer products, leverage insights from ethnographers who monitor social forces on consumer behavior.

Analyze competitive products, and monitor their advertising and public statements to identify needs they appear to be addressing. They may not be right, but they might provide useful insights.

Market segment: ICU, CCU, OR

Needs	Features	Importance	Leverage	Minimum Level	Target Level	Competitive Profile			
System	Products variety	1	High	5	10	N	P/G	F	K
	Total system proposal	4	Medium	-	CT/MRI	P/G	N	F	K
	IT solution	4	Medium ↑	CIS connection	HIS connection	N/G/P		F/K	
Function	Data storage	4	Medium ↑	Numerical value, 24H	Wave form, 96H	P/G/N/F			K
	Telemetry	2	Medium	20 beds	100 beds	N	F	K	P/G
	Portability	3	Low	1 hour	4 hour	K	N/G	P/F	
Compatibility	Measurement consistency	2	High	50	100	P/G	N	K	F
	Visibility	1	High	Four	Eight	N	F	P/G	K
	Manipulability	2	Medium	3 step/English	1step/Japanese	F	N	K	P/G
Economy	Procurement price	1	High ↑	\2,000,000	\1,000,000	K	N/F	P/G	
	Running cost	3	Low ↓	\20,000	\10,000	N/F/K		P/G	

Product lines: Middle Class Monitor

Figure 2 The result of customer needs

As we can see from figure 2, Importance and Leverage is high for Company F. However, the company is struggling in competition in product variety, measurement consistency, visibility and procurement cost. While company P and G provides the strongest measurement consistency, company N offers the widest variety of products and visibility. Regarding procurement cost, company K enjoys the lowest. From this, we can see that company N has the competitive advantage satisfying the customer needs most. In accordance with its competitive edge in the market, company N has the advantage.

STEP 3: ANALYSIS OF TECHNOLOGY IMPACT

The next step for each team is to identify the technology options available to provide, maintain, or improve important and lever gable characteristics.

Guideline for assessing technology impact:

- Identify technologies that do or might affect important leverage characteristics.
- Rank or rate the potential for the technology to maintain or improve characteristics of importance.
- Estimate relative maturity and anticipate the potential for obsolescence or substitution.
- Determine the competitive impact of the highest impact technologies:
  - Base – necessary and available to all
  - Key – source of competitive advantage
  - Pacing – technology expected to be future key
  - Exploratory – early stage with unclear potential
- Use benchmarking to compare competitors and identify "*best in Class*", investment level, experience, strengths, etc.

Features	Product variety	Total system proposal	IT solution	Data storage	Telemetry	Portability	Measurement consistency	Visibility	Manipulability	Procurement price	Running cost	Maturity (E,G,M)	Importance (B,K,P,E)	Competitive Profile
CTI/MRI	o	++	o	o	o	o	o	o	o	++	o	M	P	P/GNF/K
Image	o	++	++	o	o	o	o	o	o	++	o	G	K	P/GFNK
HIS/CIS	o	++	++	o	o	o	o	o	o	++	o	E	K	P/GNFK
New measurement parameter	++	o	o	o	o	o	o	o	o	o	o	E	E	P/GNFK
Sensor	o	o	o	o	o	o	++	o	o	o	++	G	K	P/GNFK
Integrated ASIC	+	o	o	o	++	+	o	o	o	++	o	E	P	P/GFNK
Network	o	o	++	+	o	+	o	o	+	o	o	G	K	P/GN/FK
Digital signal processing	++	o	o	o	o	o	++	o	o	o	o	G	K	P/GNFK
High lumination display	o	o	o	o	o	o	o	++	++	++	o	G	B	ALL
Large scale memory	o	o	o	++	o	+	o	o	++	+	+	M	B	ALL
Operational device	o	o	o	o	o	+	o	+	++	o	+	M	B	FN/GP/K
Flexible manufacturing system	++	o	o	o	o	o	o	o	o	+	o	G	K	ALL

Figure 3 The result of technology impact, *continued*

As we can see from figure 3, all rivalry possesses similar technology with little difference in base technology in terms of Importance. However, company P and G shows superiority in image processing, HIS/CIS, sensor, networking, digital signal processing and flexible manufacturing system compared to company F that relates to key technologies. Company P and company G superiority also includes integrated ASIC technology that will be of importance in the future.

STEP 4: ANALYSIS OF CFTP MAP

The amount of information to be used to make investment, decisions can be overwhelming, particularly to those to whom you might be presenting your conclusions. It is important to capture the key dynamics and relationship in a format that helps the teams quickly, yet thoroughly, identify options and work through the rationale, options, and likely competitive impact of each.

The output of this phase of the CFTP process is a mapping of the competitive, market, and technological environment in which they operate and the identification of a large number of investment opportunities. They use the CFTP maps to go beyond data gathering, to begin reflection and idea generation, and finally to using informed judgment to make decisions about their technology portfolio.

Figure 4. The result of CFTP Map

Performance Characteristic	Importance	Leverage	CT· MRI	Image	HIS/CIS	New measurement parameter	Sensor	Integrated ASIC	Network	Digital signal disposal	High lumination display	Large scale memory	Operational device	Flexible manufacturing system	F	N	P	G	K
The variety of products	1	H	○	○	○	++	○	+	○	++	○	○	○	++	3	1	2	3	4
Total system proposal	4	M	++	++	++	○	○	○	○	○	○	○	○	○	3	2	1	1	4
IT solution	4	H	○	++	++	○	○	○	++	○	○	○	○	○	2	2	1	1	4
Data storage	4	M	○	○	○	○	○	○	+	○	○	++	○	○	1	1	1	1	4
Telemetry	2	M	○	○	○	○	○	++	○	○	○	○	○	○	2	1	4	4	3
Portability	3	L	○	○	○	○	○	+	+	○	○	+	+	○	3	2	3	2	1
Measurement stability	2	H	○	○	○	○	++	○	○	++	○	○	○	○	4	2	1	1	3
Visibility	1	H	○	○	○	○	○	○	○	○	++	○	+	○	2	1	3	3	4
Manipulability	2	H	○	○	○	○	○	○	+	○	++	++	++	○	1	2	4	4	3
Procurement price	1	H	++	++	++	○	○	++	○	○	++	+	○	+	2	2	3	3	1
Running cost	3	L	○	○	○	○	++	○	○	○	○	+	+	○	1	1	3	3	1

Competitor profile	CT・MRI	Image	HIS/CIS	New measurement parameter	Sensor	Integrated ASIC	Network	Digital signal disposal	High lumination display	Large scale memory	Operational device	Flexible manufacturing system	Share
F Inc.	△	○	○	△	△	○	○	△	◎	◎	◎	○	14%
N Inc.	○	○	○	○	○	△	○	○	◎	◎	◎	◎	33%
P Inc.	◎	○	◎	◎	◎	○	◎	◎	◎	◎	○	○	21%
G Inc.	◎	◎	◎	◎	○	◎	◎	○	◎	◎	○	○	10%
K Inc.	△	△	△	○	△	△	△	△	○	○	○	△	9%
Relative Maturity	M	G	G	E	G	E	G	G	G	M	M	G	

Figure 4. The result of CFTP Map, *continued*

As above table, we show marks:

// Importance: Rank order 1 is most important

//Leverage: H = high, M = medium, L = low (refer to customer reaction to performance improvement)

// Technology impact: ++ = technology influence greatly (positive or negative)
+ = moderate impact
○ = low impact

// Competitors: 1 = best, 2- second best, 3 = third best; ties indicate equal performance

//Competitive profile----- ● = strong capability/high investment
□ = moderate capability/investment
○ = low capability/investment

//Relative maturity----- E = Emerging technology
G = Growing technology
M = Mature technology

CFTP map of figure 4 shows that company N leads in the variety of products and visibility that is of importance and impacts the customer most. While company P and G leads in measurement stability, company K saves the procurement cost most. These correspond to data which shows that company N accounts for 33% of the industry share.

Company P have technical and product competitive advantage in image processing, HIS/CIS, sensor, networking, digital signal processing and flexible manufacturing system technology which are of high importance and are in the growth stage. The company has the highest potential in the industry. Likewise, company G has competitive advantage in image processing, HIS/CIS and networking. Company N's competitive advantage lies only in flexible manufacturing system that is of low technical prospect.

Although company F accounts for 14% of the market share, it is hard to say that they are meeting their customer needs accurately. They also don't have competitive edge both in product and technology. Therefore, company F's strength may be explained by either having a strong sales force, established position in the market or advantage in products beside medical information monitoring system that are keeping their competitors out of their way. The company is putting great effort in medical information monitoring system with electrocardiograph at its base product and therefore they feel that their technological inferiority is a problem.

STEP 5: ANALYSIS OF PATENTS AMONG THREE COMPETITORS

CFTP map does not clarify some product/technical relation aspects. Therefore, supplementing patent analysis to CFTP map is a good orientation in future development efforts to possibly producing an unexpected windfall. It also alerts staff of the presence of competitors.

IPC	G	N	F
A61B Diagnosis; Surgery; Identification	335	233	144
G06F Electric Digital Data Processing	29	5	8
G01N Measuring Length, Thickness, or Similar Linear Dimensions; Measuring Angles; Measuring Areas; Measuring Irregularities of Surfaces or Contours	1	44	0
G06T Image data Processing or Generation, in General	14	2	0
A61M Devices for Introducing Media into, or Onto, The Body	0	9	8
H04N Pictorial Communication, e.g. Television	7	0	3
B41J Typewriters; Selective Printing Mechanisms, i.e. Mechanisms Printing Otherwise Than from a Form; Correction of Typographical Errors	0	2	7
G01T Measurement of Nuclear or X-Radiation	11	0	0
H02M Apparatus for Conversion Between AC and AC, Between AC and DC, or Between DC and DC, and for Use With Mains or Similar Power Supply Systems; Conversion of DC or AC Input Power into Surge Output Power; Control or regulation Thereof	1	5	0
H01J Electric Discharge Tubes or Discharge Lamps	5	0	0
H01F Magnets; Inductance; Transformers; Selection of Materials for Their Magnetic Properties	1	5	0

Figure 5 The result of patents map

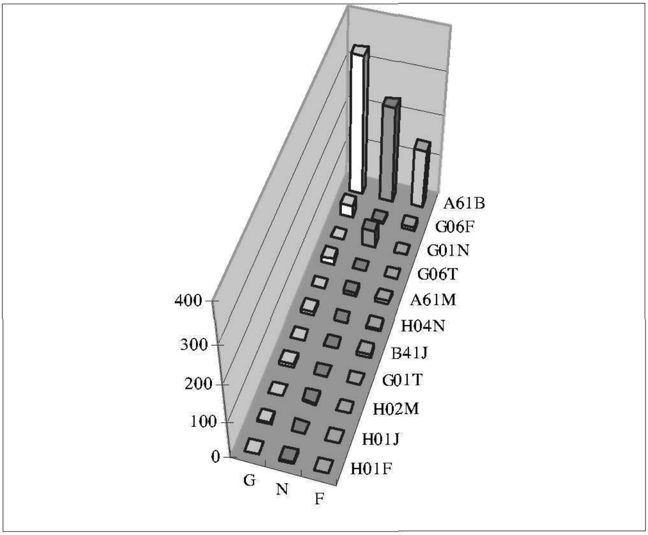

Figure 6 The transition of patents for three competitors

Figure 5 shows the number of patent application published by company G, N and F based on the International Patent Classification (IPC). The figure shows the total number published from 1993 to 2002. The International Patent Classification shown are those categories that had more than five patents filed. As we can see, all three have filed many patent in the category of diagnosis; surgery; identification (A61B).

Figure 6 shows that company G has file many in measurement length, thickness, or similar linear dimensions (G01N). Company F filing no patent in other filed is a problem in their future development orientation.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
G	0	0	0	0	0	0	0	0	0	14	178	217	16
N	2	22	51	56	38	38	21	30	27	27	40	13	2
F	0	19	45	32	5	12	12	11	8	10	24	11	0

Table 1 The number of files a patent for three competitors

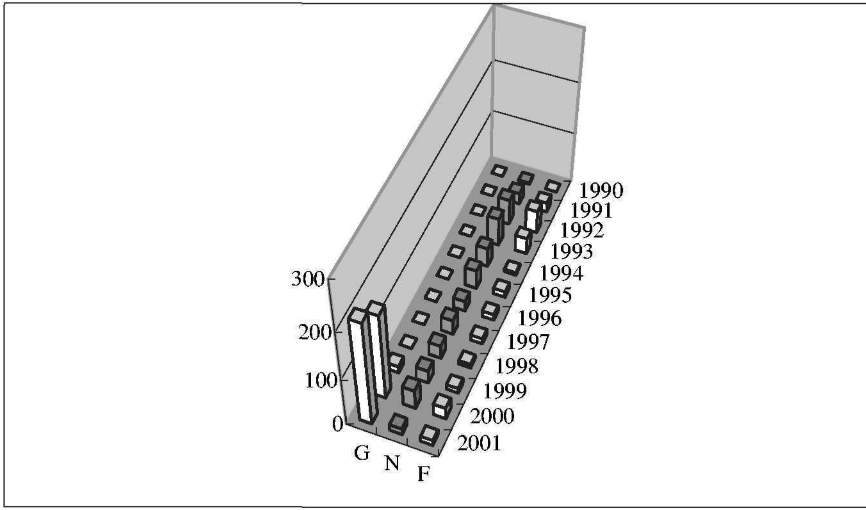

Figure 7 The result of the number of patents among three competitors

Table 1 shows the patent application statistics from 1990 to 2001. Company G shows sudden increase in its patent application from 1999 reflecting their launch into the Japanese market. For company F and N, changes are modest. The rise in 1991 can be explained by the change in the Japanese pro patent policy.

Figure 7 shows the patent application statistics from 1990 to 2001. Company G shows sudden increase in its patent application from 1999 reflecting their launch into the Japanese market. For company F and N, changes are modest. The rise in 1991 can be explained by the change in the Japanese pro patent policy.

CONCLUSION

CFTP does not tell you in what products or technologies to invest, nor does it identify options and tell you how to weight them. It merely structures and focuses the information needed to stimulate innovative ideas, clarifies the impact of technology investments on your customers and on your business, and helps you effectively and efficiently make technology investment decisions that benefit both. It is a tool to help planners think, not replace thinking with form filing.

In this research, we have conducted competitive analysis on the Japanese medical information system market especially to see whether company F's competitive advantage is secured.

Identifying company F's future direction using CFTP map created within competitive technical intelligence alone is impossible. Analyzing customer and technical needs is effective in verifying company's current status and position. Also, analyzing competitive patent information is effective to make sure of the company's orientation towards future development.

In conclusion, we have found out that there is no correlation between company F's current competitive edge in the market and it's competency in their development effort. Company F needs to verify again their customer needs in the market and orientation towards future development effort. Our next challenge is to see how we can incorporate the result of patent analysis into the CFTP map.

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SECTION III

INNOVATION – NEW PRODUCT AND TECHNOLOGY DEVELOPMENT

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

15

USAGE AND ERGONOMICS AS COMMON REFERENCE POINT FOR COOPERATION AND INNOVATION AMONG DISCIPLINES

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INTRODUCTION

Periodically generating innovative concepts is no longer sufficient today to stand out on very widely fought over markets. Innovation is not a simple effort of creativity (Hatchuel and Weil, 2002). In fact, today is admitted that to act on innovation, it is necessary to act on the quality of design. In other words it is necessary to act on its means and its organization (Laurencin, 2001).

Although design activity depends on the strategic choices of company, it is important to preserve two parallel organizations. On the one hand it is necessary to use existing resources and skills in order to meet the needs of the present and on the other hand, the company has to seek new resources and new skills in order to anticipate future needs. Thus, innovation is seen as a specific activity organized within industrial systems like recent result (Hatchuel and Weil, 2002) indicate.

But like all projects, the innovating project is a multidimensional, evolutionary and living object with human nature as an essential component (Perrier, 2001). Organized or specific, an innovating activity "must be centred on the actors and their practices" (Yung and Chauveau, 1995), especially in their relations and in the cooperation that they will be able to build. Therefore, it is very important to take into account the intrinsic characteristics of each project group's profession in order to effectively confront the various actors' representations of the project. At this time, their practices must be analysed to define the conditions of co-operation. Thus, to generate an innovation dynamic, it is necessary to put its actors into a total co-operation process to reach a common objective. A collective construction of the objectives and strategies must be carried out to create the group consciousness needed for innovation. In order to innovate through a human centred process, extracting knowledge about human behaviour is no longer sufficient; it also requires setting up a creation and knowledge transfer process based on human activity. We identify use as a broad term including several realities concerning the user's activities and practices. A cooperative process supported by approaches and tools must be set up. The question of the responsibility for driving this process must also be put.

In this paper we first intend to discuss the reasons for the necessary co-operation in design and particularly in our hand tools design process with FACOM. We will identify that a common tool for co-operation is necessary in a human centred process. Then, we will propose the theme of usage as a spark for co-operation and the generation of innovation. Finally, we will widen our reflection, compared to our action in the field, with the question of process driving and the responsibility for driving a usage centred co-operation process.

Cooperation Upstream for Co-Development. The Challenge for an Innovating Design Process

Product design is no longer the work of one single person. It is necessary to call upon several actors, from different disciplines and/or trades and to thus share several visions or representations of the product and the design process. The difficulties lie in the capacity to set up a co-operative environment in which a common discourse is adopted to facilitate communication of points of view and representations between the actors of the process. The challenge is not only "to coordinate better", but also "to cooperate better" to build the solution (Darses, 2001).

An innovating project is set up to find an unknown solution to a problem which one wants to solve. That is to find one or several innovating ideas at various levels of the design process; the innovating project requires flexibility, evolution, branching out and modifications (Perrier, 2001). Participant's co-operation around an innovating project being essential to approach complexity and to create creative space.

In these co-operative approaches, individualism is no longer desirable and must give way to a "group awareness" (David and Tarpin, 1998). This collective awareness is essential, through interactions between individuals, for the co-operative definition of the project objective. This co-operation aims to answer the fundamental question "what to make and how?" In general, this group awareness must be generated upstream of the design process by interacting in order to generate a "levelling situation" between the participants. The division of the risks related to innovating design activity (choice, decision.) is necessary for a free co-operation, which refuses that one individual assume the responsibility for a choice, and that only one point of view is used to make a decision.

A necessary upstream co-operation to take into account the user in the product design processes

Thus, to take into account the users' real activity, this upstream awareness group on the innovating project is particularly essential in our human centred design positioning. Indeed, to take into account the user in a design product step is not the simple fact of bringing new data. It is a "state of mind" (MI, 1997). To be effective and real, i.e. so that use prescribed by the design corresponds to real users' needs, this state of mind must be present in all the actors of the design process.

However, to have a state of mind it should be learned. A participative step gathering a body of what Boulier (2002) calls "representatives of the users" must be set up to build group awareness on usage. Some tools for joint design and for the diffusion of this state of mind must accompany the step for learning through the practice of this state of mind, i.e. while doing. This group awareness centred on the user must be developed as soon as possible in order to start off with the same knowledge bases. Indeed, many cases of ergonomic intervention in design projects have shown that the effectiveness of intervention is greater when located upstream in the design work. They have shown that modifications and questions are more difficult at the end of design process (Nael, 1989; Roussel *et al.*, 1996)

Taking usage into account in design projects depends on the social context of the company, i.e. of the design actors' capacity to modify their modes of communication and co-operation. Because finally, even though some approaches propose that information resulting from ergonomics is appropriable and usable by designers (Deivanaygam, 1994; Roussel, 1996), certain designers' practices slow down the effective taking into account of these parameters despite their quality. The practices of designers can indeed be directed by experience, i.e. by the confidence accorded to already tested solutions (Meister 1987). Thus, the act of designing becomes intuitive and owned by one individual. According to Broberg (1997), it is more significant to train designers and to change their mode of co-operation than to accumulate and transmit the bare necessities of ergonomic information.

The challenge for the effective taking into account of user and usage, is thus to create the conditions of co-operation from the beginning of the project, allowing the development of collective awareness about usage in projects.

INDUSTRIAL CONTEXT OF OUR RESEARCH

Our research takes take place within the framework of a CIFRE[6] program with the FACOM Research Development department. It is based on the principle of research action thanks to our active participation in a design project. This department wishes to build an approach enabling users' real use to be taken into account in its product design and innovation process.

The FACOM Group is a leader in the European hand tools market. Founded in 1918, FACOM's business activities are today focused on 13 main production sites and on 14 engineering and design departments. It also distributes its products in more than 100 countries.

Conscious of the need for taking into account the user in hand tool design, FACOM has always aimed to propose to professionals of all trades the most suitable tools for their work. Thus the company has built its marketing strategy on the "trade" concept. It has developed its own know-how and knowledge of the usage of its products and the trades for which its tools are destined. A strong marketing structure manages a "listening to the customer" process. This process is centred on customer needs satisfaction and carries out regular surveys.

Thus, projects arise from marketing detected needs. Then, during development, links with users are constructed through studies where users test prototypes. Although this step has the advantage of being integrated in the culture of the company (which is already a good basis in taking the user into account), we think that is not sufficient to identify precisely the users' needs and that all the conditions of a good market

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[6] Industrial Conventions of Formation by Research financed by the French National Association of Technical Research

anticipation (Laurencin, 2001) are not met. Indeed, the user tests carried out by designers or by the company's marketing people concentrate almost exclusively on listening to customer satisfaction. Although these data are necessary to know users' preferences, they do not explain the reasons for these preferences which are needed to make design choices. The FACOM Group does not have today a department to carry out tool ergonomics studies which can contribute to marketing studies for a joint definition of real users' needs. According to us, these two approaches are complementary, and in our organisational context, essential in the search for what Duncan (1997) calls "articulated needs".

One can thus observe a shift between the real usages of the users and the usages prescribed by the designer for the product. Design activity is then built on the representation of the users' real activity. Confronting users with prototypes happens too late to call the product into question conceptually.

In parallel, whereas all of the individuals in the company, thanks to this strong contact with users, have much knowledge about usage in a work environment, this information is not shared with designers. Some choices in design however require this information to remain in harmony with real user activity.

A participative approach to joint development for an innovating activity

A collective construction of the objectives and strategies are then necessary to create group awareness for innovation. Global approaches are emerging today with the aim of generating this joint attitude to upstream design development (Mallein, 2002; Maxant, 2002). They are called participative preconception approaches and are useful both for market anticipation (prospective) and for the genesis of innovations (development). However, an approach should be accompanied by the necessary tools in order to generate the impulse for cooperation. Simply enrolling the actors in an approach is not enough to generate interaction and participation. Certain impulses or sparks are needed to generate this sort of involvement. Impulses are thus necessary to implement interaction and innovation

However, in the processes of collective design (an activity of participative design in which all the actors are considered as experts), the essential problems are due to "linguistic barriers" between professions (Rehal, 1996). Several registers separate the participants whereas the objective is to build a common discourse. Roussel (1996) suggests "drawing up a filter" between information from different professions in order to translate information resulting from the expert analysis. He also proposes that ergonomics formalize a "Common Reference System of usage" in order to translate the ergonomic point of view of the product and to direct designers into ways of finding solutions that respond to usage. We think a shared or common set of themes, unifying all the translations of each expert, must be used to spark co-operation. Moreover, as our research is oriented towards innovation, our set of themes must also be a source of innovation.

We think that the theme of usage is sufficiently appropriate in our industrial context to respond to our problems of innovation, co-operation as well as taking into account the problem of real user needs. Thus, our research hypothesis to date can be formulated in the following way: usage is a federative theme adapted to our context, which can be the basis for sparking co-operation and the generation of innovation.

USAGE AS A SPARK FOR CO-OPERATION AND INNOVATION GENERATION

What is usage?

Today there is not one definition of usage but several. Usage is defined as an action, the fact of using something. It is also a function, a destination, the use for which something is put to. Thus, to study usage therefore involves observing, and interpreting, actions to understand how a product is used. This concept of usage is in this sense closer to that of usability and can be highlighted by ergonomic analysis in real, or realistic situations. But the significance of usage does not stop at this dimension of action, it relates to the more general dimension of practices, customs and habits. It is thus the whole of a set of social practices. Usage thus relates, in this dimension, to a number of individuals forming a social group. Usages also relates to habits, all of the practices that a person can develop for and by using something. All things considered, usage seems to be the fruit of experience and beliefs, both at an individual level (practices) and a collective level (habits). The term use thus brings together several meanings. But, these meanings are largely directed towards the same paradigm; the practices of users.

Why usage at FACOM?

In these times of fundamental technological developments, everyone admits that it is becoming necessary "to think of usages" (Stiegler, 2002). Although this term is currently restricted to the field of telecommunications, because of the rapid technological developments in this field, we think that it concerns all industrial technical objects. In our field of hand tool design, the question of usage is at the centre of our approach. Technological evolution in the field of telecommunications does not only modify users' behaviour in their technical relation with the object but also modifies their activity around and with the object. In the case of professional activity, these technological developments, as in the field of car maintenance, affect the work activity of the operators (MI, 2001). New behaviours with tools are thus observed (modification of the frequency of use, for example). New tools, including new technologies, appear and consequently generate new practices and appreciably modify the maintenance professions (evolution of training or efforts concentrated on diagnostics). These evolutions have always been present and have always been followed by industry. However, the rapid evolution of technologies and professions forces design efforts to be focused around these evolutions.

Moreover, in our experimentation context, co-operation between individuals remains difficult and most of the time functions in an informal manner. Co-operation, although of interest to all individuals concerned, is not a reality. Indeed, existing knowledge on usage within the company is dispersed. Thus contradictory data appears because it is not related to real user activity. It is true, that when observations are carried out in the field, the data collected appear contradictory at first sight. In general, and this is the case in ergonomics; these data are coordinated and find their justification after a certain period of observation thanks to the identification of determining factors in users' activity. An understanding of these determining factors can explain contradictory behaviours and practices. In our context, the factors are not known by all the actors. The contradictions observed in the practices of users, do not enable the actors to be united in their design choices.

Usage as a source for innovation

The analysis of usage can be a source of innovation thanks to the knowledge that can be extracted about a product. This contribution of new knowledge can, indeed, cause a change in the point of view of a company while calling into question its assets based on its products. Indeed, the results of use analysis can invite designers, as in the methods of creativity based on the phenomenon of coupling (Gavriloff and Jarrosson, 2002), to look at reality from an another point of view in order to change representations. But the characteristic of usage analysis is to make it possible to change representations starting from reality. Analysis of practices and usages can allow the generation of innovative concepts (Vallette, 2001) by bringing the designer new knowledge about the product.

Thus, by intervening upstream in the conceptual phases of product design, this new knowledge can change the point of view on a product because it opens other fields of reflection, which are necessary for the generation of innovation. Moreover, it is this coming together of different types of knowledge that is necessary for the exploration of new innovations (Laurencin, 2001). Thus, in our industrial context, where the product is directly related to the usage that users will put it to and where, as a work tool, it forms part of a work activity, it is, we believe, necessary to centre the process on use activity or work activity in order to innovate.

Usage as a common reference frame for unified design

Today, the passion for new technologies is leading not only research, but also the design profession towards investigating usage. The term usage has been adopted by design and research because it speaks volumes. Indeed, this term seems to have a meaning for each designer who speaks more of usage than ergonomics today. This general term tends to bring together these individuals towards the same paradigm; taking the user into account. Nevertheless, this term does not have exactly the same meaning for each of the various actors in the product design process. Undoubtedly because these actors do not have the same objectives in design. In fact, beyond an heterogeneity of meanings, we believe that it is rather the way actors view the user which is different. Use seems to be a multidisciplinary term, having several facets but linked around the same thing, the user. Mallein (2002) sees three complementary ways to treat usage, and consequently economic value, in the design of a new communicating object: ergonomics, strategic marketing and sociology. We think that this vision can also apply to tool design, because this term is not just for new technologies. If we apply this reflection to our field of hand tool design, i.e. to professional tools design, we can extend this definition of usage:

- Ergonomics, indeed, will see in use those aspects related to usability, which relates to use in the sense of utilisation (or micro usage). It will also seek to attribute a meaning in the concept of the tool for the user in a work environment according to the model of activity. This then relates to use within the meaning of work activity (or macro usage).
- Sociologists will seek the meanings of use to anticipate the potential positioning of the new products within a coherent cultural framework. In a sense, they analyse social usage.
- Marketing will be interested in the act of purchasing and will seek as well as possible to insert the new object into existing markets. This economic approach can

supplement that of the sociologist in the sense that it will seek more to define "behaviours of consumption or ways of life associated with income brackets".

- The designer will seek a coherence of use in comparison with the products offered on the market from a functional and stylistic point of view.
- Tool testers, former users, will seek to understand whether a tool is usable according to the type of vehicle configuration, for example. They will thus seek to propose methods and techniques of assembly and disassembly.

Consequently, many actors in our industrial context are owners of data on usage. Admittedly, this information is partial and one cannot restrict oneself to only one vision of usage. To understand, analyse and "think of usages" with the aim of designing, it is necessary to rebuild usage starting from all the dimensions of usage identified by the design actors. The "Common Reference system of usage" of ergonomics has no other choice than to nourish the very concept of usage through a common reference framework for all the actors in the design project. Indeed, even if various representations of usage exist between the various actors in design, they are all directed towards a common objective; the users and their behaviour with products. Thus we feel that, due to its interdisciplinary character, a definition of the multiple facets of usage must constitute the Common Reference framework necessary to spark group awareness, which is nourished and maintained by a participative approach that favours interaction between individuals in order to further innovation. Thus we think that usage can be a unifying topic in design.

CONCLUSION AND PROSPECTS

Usage seems to be a federative theme, adapted to our context, which can be the basis for sparking co-operation and innovation generation. We must, then, produce a methodological tool, a support for the rebuilding of usage, which could be transferred to all design actors and can be used as a device for design based on usage. Moreover, a global approach to co-operation must be defined in order to further this joint attitude to development organised around usage. From our point of view, it must be initially defined around the presentation of the results of the respective studies of the actors. We will use, for that, the upstream approach to generalized creativity of Maxant (2002), which is based on the sharing of common prospective analyses, and we will adapt it to our context. A common tool translating usage must, moreover, be created through our experiments in the field. Although steps and tools are necessary to organize a co-operative innovating process centred on usage, we have not answered the crucial question of how these approaches are driven. Usage alone cannot create a federative and co-operative process. Although approaches and tools can frame this sparking, it must, however,be created and generated. Even if the global company organisation can support this dynamic, who will control this process? We will then come back to the interrogations of Boujut (1998) on the question of property and the responsibility for this driving. As in the majority of companies, the design of products was, formerly, mainly driven by technical aspects. Then other strategic forms appeared in companies. The processes were thus centred on design. We do not wish our process to be centred exclusively on ergonomics. The problem of co-operation, muddied by the question of responsibilities and power structures, would not be solved in this case. Moreover, ergonomics can only partially answer the question of the users. Usage, on the other hand, by its multidisciplinary position and thus multi-ownership nature, should be at the centre of the debate. Its driving must thus be carried out by actors in frontier positions between the various professions. Boujut (1998) call them "interface actors" who could control "interface knowledge".

This question of driving also arises in our industrial context. Who indeed will manage the interface knowledge on usage? It is necessary to have managers of usage? Who will control the construction of the joint definition and the usage, at appropriate moments, of this common reference framework in design?

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16

AN APPROACH FOR MANAGING THE INTEGRATION OF NEW PRODUCT DEVELOPMENT PROCESS IN BIOTECH START-UPS

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INTRODUCTION

Today's climate of New Product Development (NPD) is characterized by increased domestic and global competition, technological development waves become shorter, continuous development of new technologies that make existing products obsolete, changing customer requirements which truncate product life cycles and rising PD costs (Gupta and Wilemon, 1990; Cooper, 1994). As product life cycles get shorter and technology seems to change at an ever-increasing pace, it becomes especially critical to have an effective and efficient NPD process (Birou and Fawcett, 1994) to improve company's performance (Cooper and Kelinschmidt, 1995).

The environment for NPD in most technologically advanced industries suggests that the difficulties and uncertainties associated with the NPD are increasing along with the pressure to develop more new products. Time pressures have become more critical as delay in delivery of NP innovations can cost firms significant proportions of related profits. Rolling out new, technically challenging products at the right time has been a key success factor for more than a decade (Iansiti, 1993). Improving the speed of product development process can be a powerful competitive advantage (McDonough and Barczak, 1991; Millson et al., 1992). But just focusing on speed to market may miss the point in that the real challenge is how to create faster, better and cheaper products, not just create them faster (Wind and Mahajan, 1997). Therefore, the scope of the NPD process encompasses the delivery of a fast, high quality, and cost-effective product (Birou and Fawcett, 1994).

To increase their competitiveness, companies that develop products have realised the importance of improving the efficiency of their development process (Browning and Eppinger, 2003). Since process improvement requires process understanding (Whitney, 1990), researchers and practitioners put effort into observing product development process - looking for its important characteristics- and developing models and approaches that account for those features (Browning and Eppinger, 2003). The reason behind these approaches is that, without an understanding of the NPD process and its constituent elements, the process will not be managed as effectively as it could be. Companies should therefore be paying increasing attention to understand and manage the NPD process (Paashuis, 1998).

More specifically, companies should understand how to integrate their NPD process activities. Integrating a complex set of activities that cuts across most functions in a business is a difficult task. To work effectively, the different backgrounds, skills and perspectives must be integrated to form an effective whole. To do so, integration approaches are needed.

While much has been written about the theory and practices of NPD process and its integration in large and medium sized companies (Paashuis, 1998; Nihtilä, 1996; Cooper, 1994), little effort has been focused on start-up companies, and much less on high-tech ones, such as biotech start-ups. The NPD theory and models, which are developed for large and medium sized companies, can barely be transferred to high-tech start-ups because of small businesses restricted resources in terms of money, labour, knowledge, experience, technology, channel of sales, and brands.

However, to be able to integrate the NPD process, it is crucial to understand the integration approach in organisation framework. What may work for one company may not work for another. It depends on the characteristics of industry, company size, and the NPD process. Some industries have more complex NPD process than others, and integrating its activities is uneasy task. Biotechnology industry is an example of these types of industries.

Biotech Start-ups

Biotechnology is one of the new rapidly developing technologies that have dramatically changed the landscape of competition in many industries. It will be the major technology of the twenty-first century (Hitt and Ireland, 2002). Biotechnology is highly multidisciplinary; it has its foundation in many fields including biology, microbiology, biochemistry, molecular biology, genetics, chemistry and chemical and process engineering. It has been considered as a series of enabling technologies involving the practical application of organisms or their cellular components to manufacturing and service industries and environmental management (Smith, 2000). The European Federation of Biotechnology (EFB) considers biotechnology as "the integration of natural sciences and organisms, cells, parts thereof, and molecular analogues for products and services."

The biotechnology industry is characterized by "hyper-competition" with a high degree of uncertainty about the combined effects of both new technologies and new market structures. In this industry, the revolutionary changes in technology and innovative new products and processes have the potential to threaten the position of existing market leaders and their product-market positions (Hitt and Ireland, 2002). It is also a sector where we find a large number of R&D alliances, in particular between well-established companies (typically old and large) and start-up companies (typically new and small) (Rothaermel, 2003). There is a certain degree of mutual dependence developed between large and small biotechnology companies. This mutual dependence in cooperative projects consisted of financial support and regulatory know-how provided by large pharmaceutical companies to start-up biotechnology companies, in return for which large companies acquired access to the research skills of these small biotechnology companies. With the increasing number of new products based on pharmaceutical biotechnology, collaboration between start-ups and large companies also provides the first group with access to new markets and distribution facilities (Hitt and Ireland, 2002). In 1999, the large pharmaceutical companies marketed and distributed seven of the top-ten selling biotechnology drugs, even none of the drugs were developed by the large companies (Rothaermel, 2003).

An example of this collaboration between large and start-up biotech companies can be taken from the new drug targets industry, where the optimum situation is to take a project from inception to approved drug (e.g. drug discovery, development, production, clinical trial phases I-III, FDA regulatory process, sales and distribution). But this is a long and extremely expensive proposition (Giovannetti and Morrison, 2000). Due to their limited resources, start-ups do not have the capability to develop its pipeline, so that they focus on their abilities (e.g. in drug discovery) and partner with established biotech companies that already have the assets in place to help with the balance of the development process. The challenge that faces biotech start-ups in this phase is how to select the right partners. Integrating the NPD process with unsuitable partner is a sort of wasting time and money.

Once the right partners have been selected, a collaborative network of biotech companies and institutes is formed to conduct the biotech project. Generally, in such a network, each activity within the NPD process tends to be carried out by a separate function within or across the company boundaries. Once the activity is completed, the output is sent to the next function in the process so they can contribute their specialised knowledge and skills to the product's development (Paashuis, 1998). In such projects, the NPD process often suffers from a lack of co-ordination and communication. Delays and over-cost of biotech NPD projects is not uncommon. The challenge in this phase is how to manage and integrate these highly interrelated but disparate activities in order to improve project performance.

This paper proposes a conceptual framework for managing the integration of NPD process in biotech start-ups that enables them to select the right partners and to integrate their development process both internally and externally. The paper focuses on the three elements of integration: Collaboration, Coordination, and Communication (3C), as a means toward an integrated NPD process. Managing a tightly integrated NPD process will result in improving company performance so as to reduce cost and time of biotech NPD projects.

In the following section, we will introduce the elements of the integration approach: Collaboration, Coordination and Communication, and their usefulness for the NPD process. Section III represents the interaction between the NPD process and the 3C within organisation context. Section IV provides the conceptual framework for the NPD process integration, and its phases. Finally, section V contains concluding remarks and idea for future research.

THE THREE ELEMENTS OF INTEGRATION APPROACH

Before we introduce the three elements of our integration approach, we will describe what exactly integrated NPD means. Lawrence and Lorsch (1986) define integration as the process of achieving unity of effort among the various subsystems in the accomplishment of the organisation's task. Hitt et al (1993) state that integration facilitates reciprocal information flow among functions responsible for the development, design and implementation of the innovations. The Product Development and Management Association (PDMA, 2002) defines integrated Product development as a philosophy that systematically employs an integrated team effort from multiple functional disciplines to develop effectively and efficiently new products that satisfy customer needs.

Collaboration

Collaboration is the process in which several people, or organisations, with different, possibly complementary skills work together to create new product designs (Kahn, 1994). Collaboration creates synergy in the activities of different individuals by creating and using a common knowledge base (Schrage, 1990), and is promoted by collective goals, mutual understanding, informal activity, shared resources and common vision (Kahn, 1994). This leads to richer communication between different functional areas, which may in turn lead to less problems in the coordination of their activities (Paashuis, 1998).

Coordination

Coordination is used here as a state variable referring to "the state of being co-ordinated." It refers to the degree to which the activities of organisations' members are fitted and linked together in order to accomplish a collective set of tasks (Van de Ven et al, 1976). NPD activities need a certain degree of coordination because individuals and functions often lack the knowledge and skills to take into account all relevant design issues, especially those outside of their specialist areas (Paashuis, 1998).

Within their own context, individuals and functions might well have sufficient knowledge and skills to do a good job, yet unless these are sufficiently coordinated, a project might still fail (Moenaert and Souder, 1990). Development lead-time, cost and product quality might suffer as a consequence of not having a well-coordinated process.

Communication

Communication is the process in which information originating in one function (sender) is transferred to and put to use by another function (receiver) (Moenaert and Souder, 1990). In other words, output information of one function is transferred to serve as input information for another, with input as well as output information comprising knowledge and know-how, such as ideas, concepts, data, results, analyses and plans. In this process, people from different functional areas share and understand information, usually with the intent to motivate or influence behaviour. Communication is enabled and facilitated by meetings, committees, telephone calls, standard forms, memoranda and reports, e-mails and other IS.

The relationship between the 3C. Although distinct, collaboration, communication and coordination are related. In particular, greater collaboration will increase the need for coordination and communication since working together requires greater information sharing and greater accessibility to the other party's resources. The converse is not true. Communication and coordination will not necessarily promote collaboration. This relationship is represented in figure 1.

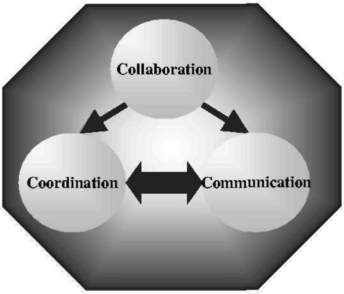

Figure 1: The relationship between the

Benefits of Integrating the NPD Process

Several studies found integrating NPD activities to be an effective way of overcoming problems related to long development lead times, poor manufacturability, rework and product below customer expectation (Clark and Fujimoto, 1991; Voss et al, 1991; Ettlie, 1994).

However, by having an effective integrated NPD process management approach, there is a good chance that less rework will need to be done, because the work of different functions is carried out with due regard for the relationships among the various parts, components and production process. Development lead-time and cost might be lower in this case (Paashuis, 1998). In addition to that, well-integrated process leads to a systematic transition of function's output to be the input of other function at the right time; this may result in overlapping of activities.

Moreover, the integration approach allows the start-up management team to see the NPD process as a whole, which will help in having the right decisions and speed-up those decisions. All of which will lead to reduce the NPD projects cost and time. However, there are three levels of benefits that can be gained by start-ups:

(i) Project level: developing a new product with less time and cost,
(ii) Company level: Fast Return on Investment (ROI), and cash to start a new project,
(iii) Business level: the company gain a competitive advantage.

THE INTERACTION BETWEEN THE NPD PROCESS AND THE 3C WITHIN AN ORGANISATION CONTEXT

The best way to view the link between the NPD process and the three elements of integration, within the organisation context, is through an organising diagram, see figure 2. However, NPD process requires significant interaction with different levels of an organisation for success (Thomas, 1993). As shown, the NPD process management reacts with two different organisational levels, strategic and operational levels.

In the first level, the strategic level, as the limited resources force the biotech start-ups to collaborate with other biotech companies, it has to be decided which NPD activities should be carried out in-house, and which should be outsourced. An important consideration is the strategic relevance of certain technologies for a start-up. The next important issue is how to select the right partners to execute the outsourced activities. Such decisions are of strategic importance for start-ups (Badir et al, 2003) and keys to the success of their NPD projects. To be able to take the right decisions, at this level, start-ups should have a clear defined vision and strategy (e.g. growth ambitions, future the start-ups aiming to, disease or technology area, etc.).

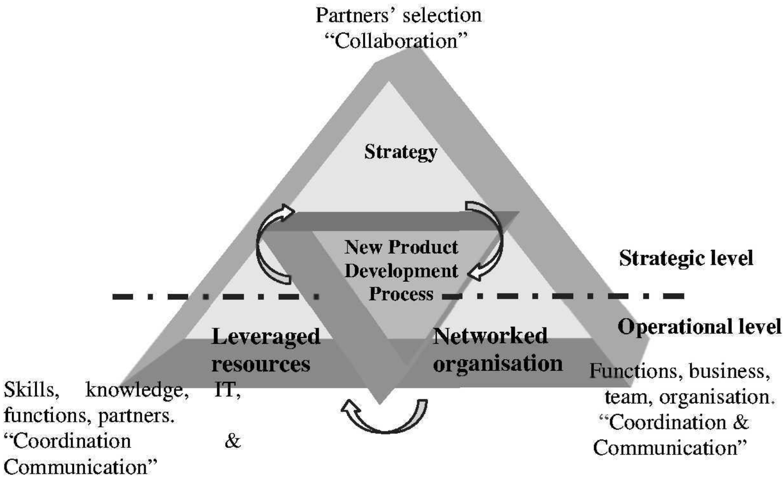

Figure 2: NPD process and 3C in organisation context

In the second level, the operational level, once the start-ups have decided what activities to outsource and selected the right partners, the main question is: how to build a collaborative network of different-focused organisations, what is the best technique to have resources, both tangible and intangible, productively shared between network members, and what approach leads to effective communication and coordination of the NPD process activities internally (different units in the start-ups), and externally (with the network members).

The coordination element aims at streamlining the transition of output from one activity to be the input for another activity, eliminate re-work, and introduce the overlapping of activities. The communication element aims at ensuring the right information are sent to the right place at the right time. The start-ups deal with some issues such as what level of knowledge sharing should they have to allow them to speed up their decision-making, do they need accessible information server with the partners, do they have a sufficient IT infrastructure assisting good communication, do they need to invest in IT to move forward.

THE PHASES OF INTEGRATION PROCESS

As mentioned before, the integration approach is not something that can be "bought off the shelf" and implemented in start-ups NPD process without efforts. There are many factors should be taken in consideration to have an effective integration approach, such as the start-up's strategy, the nature of the NPD project, the characteristics of the network, the available and required resources, and the technology needed.

The proposed integration approach gives biotech start-ups a means to design their NPD process integration that fit best into their business and project activities. Several choices have to be made, by the start-ups management teams, within the framework of this approach. To have the right choice, the proposed approach provides a different set of issues in different stages. Those issues serve as a guide toward integrating the NPD process.

As shown in figure 3, the integration approach consists of three different phases, identification, partner selection, and integration elements phases. In the first phase, some identification work should be carried out. The goal of this phase is to understand the current situation of the start-ups. The results of this phase will be used latter to select the right partners. However, the start-ups should identify clearly their vision, and their short and long-term strategies. Most strategists agree that the two key questions of company strategy are: what business should the start-up be in, and how to get there (De Wit and Meyer, 1999). Moreover, the start-ups should also identify the development project goals. The development projects should be in-line with the start-up's strategy. The third element in this phase is the "internal resource analysis". An internal analysis of the start-up's resources helps to identify the start-up's specific strengths and weaknesses and its source of competitive advantage.

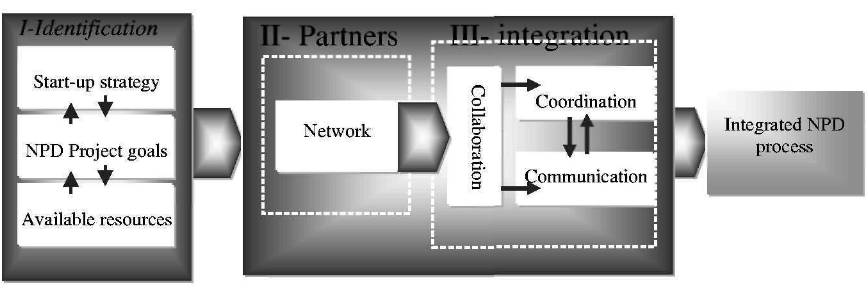

Figure 3: The Three Phases of Integration Process

The second phase is the partner selection. The goal of this phase is to select the right partners and segment those partners along a spectrum of limited to deep collaboration. The result of this phase will be used latter to manage the collaboration, communication and coordination of NPD process activities. Start-ups are not expected to invest the same effort, in communication and coordination, with all partners. The more strategic the partner, the better the communication and coordination. However, as stated before, there is no biotech start-up that has the time or resources to develop all the needed capabilities internally. The only way to overcome this obstacle is to collaborate with other partners. The strategic partners should meet the following requirement: share the same vision for the business, of great importance to development projects and business, current and future business size matching with the start-up plan, can help to have a short-term return, defined long-term potential, and help in improving the NPD process performance.

The third phase consists of three interrelated elements, collaboration, coordination and communication. The goals of this phase are to ensure that: (i) the people, units and functions within the company or/and from different companies are working and collaborating together for achieving the NPD project goals, (ii) there is a certain degree of which the activities of NPD process are fitted and linked together in order to accomplish a collective set of tasks, and (iii) the upstream functions have knowledge of downstream capabilities in order to incorporate these into their activities.

In order to design a good level of integration, the NPD process activities should first be broken down into sub-process and tasks. Followed by finding out the functions of each task, the required input and output of each task, supporting tools, milestones and deliverables, feed-back loops, criteria for transition from one phase to another, etc. When breaking down and scheduling NPD process activities, the relationship between the activities of different people and functions will be clear. The next step is to find out where coordination and communication are required or have to be enhanced along the process. This step will help in introducing the overlap of activities, which results usually in reducing the time and cost of NPD projects.

CONCLUSION

Biotech tech start-ups are keenly interested in improving the performance and integrating their NPD process as to reduce the time and cost of their projects. Integrating a complex set of activities that cuts across most functions in a biotech industry is a difficult task. To work effectively, the different backgrounds, skills and perspectives must be integrated to form an effective whole. To do so, integration approaches are needed.

In this paper, a conceptual framework for managing the integration of NPD process in biotech start-ups has been presented. The framework enables the start-ups to select the right partners and to integrate their development process both internally and externally. The approach consists of three different phases, identification, partner selection, and integration phases. This paper focus on three elements of integration: collaboration, coordination, and communication, as a means toward an integrated NPD process. This integration approach allows the start-up management team to see the NPD process as a whole, which will help in having the right decisions and speed-up those decisions. All of which will lead to reduce the NPD projects cost and time.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
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17

ANALYSIS OF THE INNOVATION PROCESS WITHIN ITALIAN SMEs

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SMEs AND NEW PRODUCT DEVELOPMENT: INTRODUCTION

The development of many industrialized countries is based on Small and Medium Enterprises (SMEs), which operate around the large firms and form the basis for a solid industrial system and contribute to the development of the principal macroeconomic variables. The flexible structure allows the SMEs greater adaptability in the face of the present turbulent world scenario (Emery and Trist, 1965). Within the innovative activities the development processes of new products play a basic role in encouraging the accumulation and integration of knowledge. In spite of their importance, in SMEs the product development processes are often only slightly formalized due to their pervasiveness with respect to the various firm functions and the considerable risk inherent in any innovative activity. It is in fact necessary for the firm to identify and to match new products (or services or processes) with the client's real needs, using their own technological competence with an acceptable level of risk. Managerial literature has attempted to avoid these difficulties by offering a number of publications (Roussel *et al.,* 1991; Slywotzky *et al.,* 1997; Balachandra, 1989; Ulrich and Eppingen, 1995) focusing on the most efficient management procedures. However, the activity that precedes the development of the product has been largely ignored and continues to remain in the shadows.

The purpose of this research is to analyze the strategies formally or informally adopted with respect to the innovation process in a sample of SMEs located in the northwest Italy. The research analyses both the New Product Development (NPD), and the cases where the development of a product is characterized by the continuous improvement (incremental innovation) of existing products. The research analyses the behavior adopted consciously or instinctively with respect to the innovative process by the SMEs in the phases preceding a formal NPD project, and in all those cases in which it appears difficult to isolate the NPD due to the presence of continuous improvements in existing products.

Many types of SMEs are present in the economic environment, which, according to the innovative level, can be catalogued (Hoffman *et al.*, 1998)[7] in:

- *Superstar firms*, these are SMEs that have benefited from the high levels of diffusion of radical innovations in the fields of technological trajectories such as semi-conductors and software. Studies have shown that the principal challenge that the management of superstar firms must face is the progressive translation of the initial innovation to the new production lines.
- *New technology-based firms (NTBFs)* are a recent phenomenon and involve SMEs born thanks to spontaneous spin-off from larger firms and research laboratories, above all in the electronics, software and biotechnology sectors. Generally these firms are specialized in offering strategic components, subsystems, services and technical applications to larger firms.
- *Specialized supplier*, these are traditional businesses focused on the design, development and production of specialized productive input, in the form of machinery, instrumentation, components and software, and capable of interacting proactively and in conjunction with their technical client. These SMEs carry out very little formal R&D, but they are an active source of development of main innovations deriving in particular from the contribution to the technical and production units.
- Finally many SMEs come within the category of the *supplier dominated.* About innovation, these businesses strongly depend on their suppliers and clients. In these firms the technology will become more important in the future following the potential applications of the information technologies, above all in the field of logistics and coordination of the activities, as in the case of NPD.

[7] Hoffman's *et al.* classification deirves from the well-known taxonomy by Pavitt (1984) with a specific adaptation to the innovative degree of the small and medium businesses.

For each of the above types of SMEs the development activities of new products and processes are the basis for entrepreneurial success. Moreover the SMEs are often very informally organized due to the lack of R&D departments, the lack of graduate technicians, the direct involvement of the entrepreneur in the innovative process. These are all elements far from the concept of *continuous improvement* (Caffyn, 1996). This represents a weakness within the innovative process as was shown by specific studies relating to the United States. This situation appears even more worrying if we analyze the European SMEs, and above all Italian firms operating in sectors that are largely mature, or at least with low content of innovation. A research carried out by Ceris-Cnr Institute in Italy shows as the SMEs located in the north west Italy are strongly concentrated on the lower levels of continuous improvement, that is spontaneous or natural. The formal level is evident within some firms where there are strategies of *problem solving* (e.g. mechanical engineering industry).

The failure of the European SMEs to develop radical innovations is subject to particular attention from public policies at all levels of government. Unlike larger firms, SMEs tend to be specialized rather than diversified in their technological competence. This research aims to offer some useful remarks to the European policy makers and managers in managing NPD and innovation within SMEs.

This article is structured as follows. The next section describes the method of analysis in detail. The results that emerged are described in section 3. Finally, section 4 sets out concluding remarks and managerial implications.

RESEARCH METHOD

The research was conducted as part of an Interreg project organized with the University of Savoy (France), CRITT (Centre Régional d'Innovation et de Transfert de Technologie) of Savoy (France) and COREP (Consortium for the Research and Education) of Torino (Italy). The purpose of the Italian institutions was to study in-depth the process of NPD within SMEs using economical and managerial approaches. Moreover, we had remarked that as the regions are close the behaviour of the small firms is similar, therefore the French institutes had to use the results of Italian laboratories to a software support package for setting up innovation projects (Chanal, 2002).

Definition of the sample

This phase started with the careful selection of the SMEs located in one of the most industrialized areas of Italy (NorthWest), province of Torino. These firms are mainly supplier dominated (automotive industry), although this strategic policy has recently begun to undergo transformation. The methodology is based on a small sample because the aim of the paper is to deeply investigate the structure and the innovation strategy of a set of case studies.

The fundamental characteristics taken into account for the definition of the sample was: 1) matching SMEs categories as defined by the European Union (EU); 2) specialization in manufacturing sector; 3) autonomous capability in NPD.

The sample was selected according to a combination of Bernoulli sampling and by direct calls to firms known to possess planning know-how. Finally the sample was balanced between firms working on catalogue and on jobbing, in order to highlights the possible organizational differences between the two different productions.
The sample is formed of 17 firms whose characteristics are shown in table 1.

Table 1 - Characteristics of the sample

	No.	%
Type of selection		
Direct call	9	53
Casual	8	47
Total	17	100
Number of employees		
From 0 to 49	4	24
From 50 to 149	8	47
From 150 to 250	5	29
Total	17	100
Industrial sector		
Electronics	3	18
Instrument manufacturing	5	29
Software	2	12
Component manufacturing	7	41
Total	17	100
Production		
By catalogue	6	35
On jobbing	6	35
Both	5	29
Total	17	100

Questionnaire

The questionnaire is structured in three horizontal and vertical levels as shown in table 2. Each point of the first level includes a series of sub-points, described in level II, each of which gathers information using a series of questions that represent the third level of the questionnaire.

The underlying logic of this subdivision is to carry out a wide-ranging analysis of the various firm activities, according to the model of the value chain (Porter, 1985). The idea is to identify the creative sources, the causes of greatest cost, the strengths and weaknesses and the factors that can potentially be transformed into competitive advantages. The analysis of the data will allow us to construct the strategic orientation

(Ansoff, 1987), on the basis of two criteria: the product (present and new) and the market (present and new). Moreover, considerable attention will be on the analysis of vertical integration, beforehand and afterwards, of firm activities belonging to, or close to the value chain.

Table 2 - Structure of the questionnaire

LEVELS		
I	II	III
1. Definition of the project	a) Project assessment b) Client assessment c) Evaluation of client expectations d) Market assessment e) Evaluation of market potential f) Assessment of competition g) Assessment of knowledge and resources required	Each point has a variable number of questions, from a minimum of three to a maximum of five
2. Product features and environmental factors	a) Product specifications b) Context surrounding the project c) Scenario and evaluation of risk	Idem
3. Orientation to be given to the product	a) Positioning of offer b) Preliminary analysis c) Decisions on project orientation d) Organization of project	Idem

Gathering and analysis of data

The basis for gathering an investigating of the data was the longitudinal study method (Leonard-Barton, 1990; Langley, 1996) based on (interviews, documents and direct observations), necessary for gathering different types of data and carrying out crosschecks. The aim of the triangular approach is to use different points of force for the various methods of data collection. The interviews supplied in-depth information, subtleties and personal opinions of the interviewees. The documents – gathered from the firms' Internet sites, from firm brochures, from public databases – gave information on the number of employees, turnover, balance sheets, geographical location, markets and so on. Finally, direct observation in the firms offered access to a number of processes and helped researchers to compare the discrepancies between the answers obtained from the interviewees and the firm situation. During the research every effort was made to avoid possible Howthorne[8] effects in the comprehension of the process of the research and NPD.

Data gathering was carried out according to iterative processes. The research involved a number of interviews in the firms over a period of 12 months, with intermittent contacts. During the meetings in the firms two researchers met with the entrepreneur or and/or managers (the managing director, production or marketing managers, research directors, persons in charge of innovative components, etc.).

The results of the research are described in the following paragraph, where a transverse evaluation was carried out with the aim of highlighting best practices within the sample firms.

RESULTS AND DISCUSSION OF THE SMES INNOVATIVE PROCESS

The characteristics used for selecting the firms can be utilized as a basis for the segmentation and analysis of the sample. In particular the size of the firm, the industrial classification according to the taxonomy of Hoffman *et al.*[9] and the production typology (work on catalogue or jobbing), will be taken into consideration. Other variables were added to the answers that emerged from the questionnaire, such as: a) the definition of the target if the project is complementary to the needs expressed by the customers or predefined within the firm; b) which competitive variable between innovation, quality and price most affects firm strategy; c) whether the firm operates in a dynamic or static market. By cross-referencing these variables we find, for instance, a difference between the firms with 150 employees and SMEs. In fact, the medium size firms all operate in dynamic markets, mainly predefining the targets for the projects, basing their decisions on the competitive variables of quality and innovation, and producing completely on catalogue (table 3).

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[8] The Howthorne effect is present in all experimental works that involve human beings: anyone included in an experiment knows that their behaviours is subject to analysis and therefore tends to modify their natural behaviour.

[9] The classifications of superstar and new technology–based firms, being relatively rare, were gathered in a single category called innovative SMEs.

Coherently with their productive organization all the firms that work on jobbing declared that they only made changes in project targets if requested by the client, while those who produce for stock define the product target internally. The former operate in static markets aiming above all at price, the latter are influenced by dynamic competition and must improve the product in terms of innovation and quality (table 4).

As far as the sectorial subdivision is concerned, according to the taxonomy of Hoffman *et al.* (1998), no particular features were found except for firms operating in innovative sectors. These firms are mainly affected, as was to be expected by the innovation, but the price and the quality also affect some innovative SMEs. The markets of the specialized supplier are mainly dynamic, while the supplier dominated firms rarely pre-define the project targets and tend to use the price as a competitive variable (table 5).

Table 3 - Division of sample according to the size of the firm (% value)

	Nos. employees			
	0-49	50-149	150-250	Total
Definition of the project target				
Complementary	75	75	20	59
Predefined	25	25	80	41
Total	100	100	100	100
Evolution of market				
Dynamic	50	38	100	59
Static	50	63		41
Total	100	100	100	100
Production typology				
On catalogue	25	13	80	35
On jobbing	50	50		35
Both	25	38	20	29
Total	100	100	100	100
Predominant competitive variable				
Innovation		13	40	18
Price	75	38		47
Quality	25	50	60	35
Total	100	100	100	100
Hoffman et al. taxonomy				
Supplier dominated	75	25	40	41
Innovative SMEs	-	38	40	29
Specialized Suppliers	25	38	20	29
Total	100	100	100	100

Table 4 - Division of sample according to production (% value)

	Production			
	Both	On catalogue	On jobbing	Total
Definition of the project target				
Complementary	80	0	100	59
Predefined	20	100	0	41
Total	100	100	100	100
Evolution of the market				
Dynamic	60	100	17	59
Static	40	0	83	41
Total	100	100	100	100
Predominant competitive variable				
Innovation	20	33	0	18
Price	40	0	67	47
Quality	40	67	33	35
Total	100	100	100	100
Hoffman et al. Taxonomy				
Supplier dominated	60	17	50	41
Innovative SMEs	40	33	17	29
Specialized suppliers	0	50	33	29
Total	100	100	100	100

Table 5 - Division of sample, classification according to Hoffman *et al.* taxonomy (% value)

	Classification according to Hoffman et al.			
	Suppliers dominated	Innovative SMEs	Specialized suppliers	Total
Definition of project targets				
Complementary	86	40	40	59
Predefined	14	60	60	41
Total	100	100	100	100
Evolution of market				
Dynamic	43	60	80	59
Static	57	40	20	41
Total	100	100	100	100
Predominant competitive variable				
Innovation	0	60	0	18
Price	57	20	20	47
Quality	43	20	80	35
Total	100	100	100	100
Production typology				
On catalogue	14	40	60	35
On jobbing	43	20	40	35
Both	43	40	0	29
Total	100	100	100	100

Definition of the project

In defining the project, two aspects were analyzed: the innovative source and the evaluation analysis of the client needs. This was done in order to compare two crucial phases, which lead, to the decision to begin the NPD and which generally derive from differing firm functions. The innovative sources can be schematically subdivided in: a) external (direct clients, indirect clients, or more generally the market); b) internal, including the entrepreneur, the R&D function or interfunctional teams. The individual entrepreneur may carry out the evaluation of the clients' requests through the commercial network, by the marketing function, or by the product manager. Table 6 shows that the principal innovative sources for the firms in the sample are the market and the interfunctional teams (respectively 29%), and only to a limited degree the entrepreneur. This is partly an unexpected result, above all as far as the valorization of the teams is concerned. Moreover this is a sign that this organizational structure is progressively spreading in SMEs, and the role of the entrepreneur, to whom in the past the responsibility for generating new ideas was assigned, is being reassessed. This could be due to specific characteristics of the sample. In a previous research on a larger sample of the same area (Rolfo, 2000), we observed that the degree of the entrepreneur was higher.

The role of the entrepreneur is of more importance in the evaluation of the needs of clients but in any case, not in a majority position. Moreover, from table 6 it is possible to see that within the firms in the sample there is dispersion amongst the possible combinations of sources of innovation and evaluation of the clients' needs, that is to say, there are no prevailing methods for definition of projects. The comparison with the variables that characterize the sample shows that the market is the principal source of innovation for SMEs: in particular for firms that compete on price, who work on jobbing in static markets or intervene only in a complementary manner in the definition of the new product. The interfunctional teams are significantly the principle creative forces in medium size firms with more than 150 employees, for those who produce for stock or focus on quality as a competitive variable. In the first cluster of firms the entrepreneur mainly carries out the evaluation of the clients, while in the second the marketing function is responsible.

Table 6 - Organizational aspects in the definition of the project (% value)

	Who evaluates customer needs				
Source of innovation	Sales network	Entrepreneu r	Product Marketing	Marketing	Total
Market	6	18	6	-	29
R & D	-	6	6	12	24
Entrepreneur	6	12	-	-	18
Internal teams	6	-	12	12	29
Total	18	35	24	24	100

Market assessment

The market assessment makes it possible to extend the analysis from the medium-short run of the decision to develop a new product, to the interpretation over a medium-long run of the competitive evolution. In this case, we considered the organizational aspects, which is to say by who and how the market assessment is formed. Although the questions on the questionnaire were not guided, in both cases there was polarization around the entrepreneur. In particular the answer to the question about who carries out the market analysis was the entrepreneur in 59% of the cases, and in the remaining firms various functions such as marketing, the commercial network or the R&D department. On the other hand, as far as the method for assessing the market is concerned, three methods were mentioned: personal impressions of the entrepreneur, trade fairs and internal interfunctional meetings. In this case, too, the most frequent answer was related to the entrepreneur (41% of the sample), while trade fairs and internal meetings were attributed respectively 24% and 35% of the answers (table 7).

The results show that the assessment of the market is carried out by entrepreneur in:

- firms with less than 50 employees;
- where the competitiveness is based on price;
- the production is on jobbing;
- the competition is static and it is not necessary to independently establish the content of the project.

The same can be said for the evaluation of the market. The impressions of the entrepreneur or the insight gained during trade fairs are ways that suit the traditional entrepreneurial activities, which are not affected by innovation or quality. In the presence of high levels of competitiveness, the SMEs must operate proactively towards the market and be of reasonable size. In such cases it is interesting to observe the use of organization forms based on cooperation and collaboration between the various firm components.

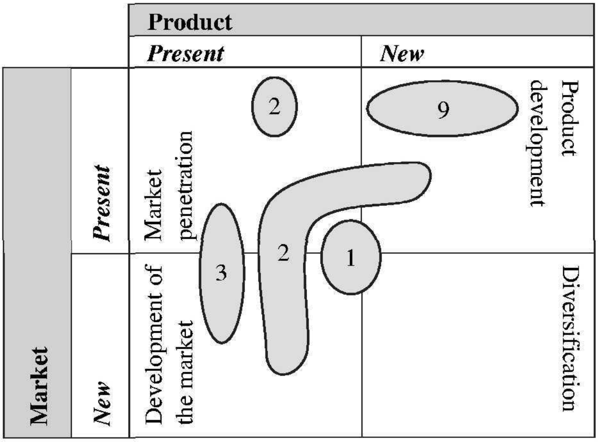
Table 7 - Market assessment (% value)

Who carries out market assessment	How market assessment is carried out			
	Entrepreneur's assessment	Trade fairs	Internal meetings	Total
Other functions	-	6	35	41
Entrepreneur	41	18	-	59
Total	41	24	35	100

Strategic orientation

The firms interviewed showed differing organizational approaches both towards the product and the market assessment. According to Ansoff (1987), the firms may continue to make incremental improvements to their products or decide to develop completely new ones, or they may decide to penetrate lateral market segments with their products, or to diversify the production in new markets (figure 1).

Figure 1 - The strategic orientations of Ansoff



These goals can be observed in the firms in the sample which, as already emphasized, for the purposes of the research are all firms capable of making at least incremental improvements to their products and therefore to actuate at least the strategy of market penetration.

The market penetration is the simplest strategic orientation and consists mainly of supporting competitive positions within the sector, based on price, as in the case of the two firms in the sample that have made only minimum innovations in the product. From the market penetration the firms can evolve towards the adaptation of existing products in similar production segments (market development). They extend thus the market and the economies of scale (three firms), or seek to differentiate their products and consequently acquire a competitive advantage with respect to their rivals in the sector: product development (nine firms).

The contemporary adoption of multiple strategic orientations is more complex. In fact two SMEs are dedicated to the development of both new markets for present products and the NPD for the present market. Finally, only one of the firms interviewed has diversified the production developing new products for new markets and making use of other strategic orientations.

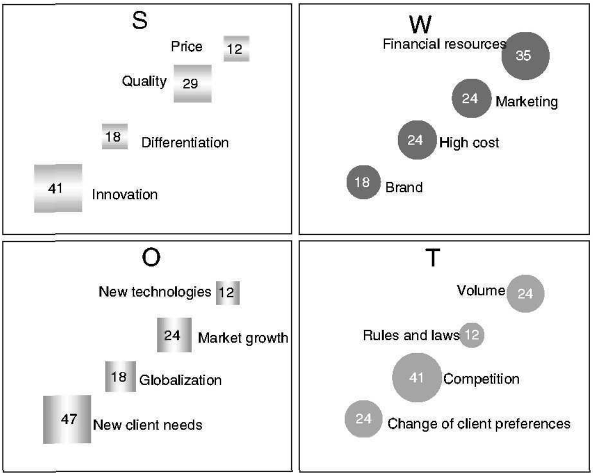
From the answers to the questionnaire it is possible to see a coherent relationship between the strategic orientation and the organizational structure. The five firms that have adopted only the strategy of penetration or the market development (in other words they have not developed new products) are:

- operating in different sectors;
- of differing sizes;
- linked by the fact that they work on jobbing.

Moreover the source of innovation within these firms is external, the project targets are complementary, markets and clients' requirements are evaluated in a traditional manner. The remaining twelve firms show heterogeneous structures in which the methodologies are focused exclusively on the entrepreneur or are extended to other firm components in evaluating client needs or assessing the market. Moreover, the source of innovation is exclusively internal and the interfunctional teams and the R&D department prevail.

Closely connected to the analysis of the strategic orientations is the SWOT analysis (strengths and weaknesses, opportunities and threats). Figure 2 shows the results.

Figure 2 - SWOT Analysis (% value)



Project management

The analysis of the project management methods was mainly concentrated on four aspects, each of that allows us to implicitly evaluate the importance attributed by the firms in the sample to the process of NPD. In order of adoption we can see that all the firms use the techniques for pre-definition of costs. The forms of innovative coordination such as interfunctional teams and product managers have been introduced respectively in 41% and 35% of cases and the programming of design times has been introduced in 59% of firms. Moreover is positive to emphasize the wide use made of these operational methods in SMEs, while on the other hand it is essential to point out the incongruities above all in those firms that have adopted forms of participation in the process management, but not scheduling techniques for design times.

Finally, although all the firms in the sample use at least one technique of cost management, the greatest risk linked to the NPD concerns the non-attainment of the cost objectives (41%). The other unknown factors refer to the non-attainment of project targets (24%), non-respect of deadlines for the product launch (12%), incorrect forecasting of sales volumes (12%) and changes in legislation (12%).

CONCLUDING REMARKS

The development activities surrounding new products and processes are essential for firm success, but in spite of their importance they are rarely formalised due to their characteristic of pervasiveness with respect to the various organisational functions and due to the dangers inherent in any innovative activity. It is a question of identifying the real clients' needs and creating new products (or services or processes) to meet them, using technological skills with an acceptable level of risk against a realistic forecast of economic return. However the activities that precede product development within SMEs are low dealt with in managerial literature. This process is often left undefined due to the strong creative thrust and the uncertainty that dominates the phases of the NPD. This situation appears even more worrying if we analyze the SMEs operating in mature or low-innovation sectors.

In this research, we examined the behavior unconsciously or naturally adopted in the face of innovation, both during the phases preceding NPD and in those cases in which it is difficult to isolate the NPD due to the presence of continuous improvement strategies for existing products.

Specifically, for the definition of the projects, in this research we analyzed the two phases that lead to the decision to begin the NPD: the source of innovation and the subject within the firm who evaluates client requirements.

Some of the results that emerged were to some extent unexpected. The principal sources of innovation are the market (market-pull innovation), the internal teams and only to a limited degree the entrepreneur. This is a sign that interfunctional work methods are spreading in SMEs. The entrepreneur assumes greater importance in the assessment of client needs. This activity is rarely assigned to the marketing function, but it is often delegated to the product manager or the sales network. If on the one hand the central position of the entrepreneur as source of innovation diminishes, the capacity for conditioning the market assessment remains considerable. It is also possible to see a majority of external sources of innovation, such as the market, in SMEs, which traditionally compete on price, who work on jobbing in static markets or intervene only in a complementary manner in the definition of a new product. Interfunctional teams are the principal creative thrust in the more dynamic firms (with more than 150 employees), who mainly produce for stock or who focus on quality as a competitive variable. In the first group of firms the entrepreneur mainly carries out the assessment of the clients, while in the second the marketing function is responsible. This research shows that the role of the entrepreneur is in a transition phase. In the more dynamic firms the source of innovation and market assessment are left to specific experts and this occurs to some extent in SMEs operating in stable markets. In firms that must innovate, even if only incrementally, the entrepreneur will continue to play a central role of coordination.

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Management of Technology: Key Success Factors
for Innovation and Sustainable Development
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18

PRODUCT DEVELOPMENT STRATEGIES FOR HIGH-TECH PRODUCTS IN A GROWTH MARKET

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INTRODUCTION

A new product is recognized in a market just after the product introduction. Shortly thereafter, a rapid market expansion occurs. This market condition is known as the growth stage in a product life cycle. Two major characteristics of this market condition can be identified in this fast growing market. One is an increase in the number of competitors, and the other is a change in the customers' product preferences. This competitive situation continues until at least the middle of the growth stage. Therefore, organizations must develop new product development strategies for successful new market entry for this stage. The purpose of this research is to introduce the development of strategies and to define the feasibility of these strategies using a case study of the Japanese portable MD player industry. In this research, the market characteristics in the growth stage are analyzed in detail and the product development strategies corresponding to the market characteristics are developed by considering current products of each organization in the market.

TARGET CUSTOMER AND MARKET POSITION

Classification of product adopters

After the new products are introduced to the market, the products are purchased by the customers and penetrate the market. In the new product adoption process, the product adopters are classified by the characteristics of their product adoption manners. By the spreading process of new products to the market, the target customers are classified into five types, from the product introduction to withdrawal.

In the growth stage, three out of five customer types can be recognized. The corresponding customer groups are explained as follows:

Innovators. They recognize the brand-new products as products with potential flaws due to its newness, but they are willing to buy the products. The value of product's newness attracts this customer group. Innovators are the adventurous customers and/or risk takers.

Early adopters. For spreading the new products smoothly to the market, early adopters are the most important customer group because they are the opinion leaders. They are moderately reformist customers.

Early majority. They are influenced by the early adopter group. They are prudent and purchase new products carefully to avoid risks such as product flaws.

Competitive position in growth stage

In this research, the strategies are developed for the each competitive position in a growth stage. The speed of market growth in a growth stage is faster than the speed of a maturity stage. Therefore, the market predominance among organizations is made by their market entry time. A new exploitation of the market is also preferentially acquired by the early entry organizations. The late market entry organizations' targets are the customers outside of the market which the preceding entry organizations do not cover. The products of late entry organizations should be differentiated with the products of early entries. By focusing on the characteristics differences of target customers and market entry time, the strategic market positioning for the growth stage can be selected. The detailed explanation in each market position is explained below.

Leader. Since the leader carries out quick market entry, the first target customer in the growth stage is in the process of changing from the innovators to the early adopters. Therefore, market leaders must introduce new products to a new market to capture this customer movement. Less product quality which does not lower the customers' good impression of the products is acceptable. The early adopters purchase new products upon considering some risks in the most of cases.

Challenger. A challenger follows in the leader's footsteps and enters into the new market. The target markets are the customers in the early adopters and early majority groups. The products for the targets must be with mid to high quality level. The new products with a full line like a leader's product line are necessary for the early majority.

Follower. As a strategy for the market follower, a market share from the leader and the challenger is gained by the competitive products. The product quality of price suitability is made by imitating the popular products, which the leader produces for the customers of the early majority.

CONCEPT FOR STRATEGY CLASSIFICATION

In the case of aiming at the whole market, Organizations must have the product development ability corresponding to the rapid increase in product preferences. New products introduction with sufficient price width which covers a wide variety of product preferences is necessary. In this condition, organizations must have the product development ability corresponding to introduce a wider variety of products. On the other hand, as the target is only a part of the market, an identification of customer's product preferences is important. The developed strategies in this research differ greatly depending on selection of the target market and the time of the market entry.

In this research, the target customers for the suggested strategies are set from innovators to early majority. When setting innovators as a target, it is necessary to gain customer's interests by the newness of the products and the products distinction from past products. On the other hand, in the case of the target of early majority, it is necessary to analyze popular products in detail. After the popular products are analyzed, similar products should be introduced to the market quickly. The products must be lower priced than the current products in the market. If the target market is small, introduced products must fit the specific product preference. The developed products must have a higher level of product originality as well as be reasonable priced.

Analysis of degree of product variety

In the concept of product development strategies in a growth stage, the organization's target customer differs by the market entry time. The target market size is also selected depending on the product characteristics and varieties of each organization. Then, measurement of the product variety is used in order to measure the size of the organization's target market. After the new products are introduced to the market, customers begin to buy the products. The first customers are called innovators, next are the early adopters, and the last customer group is the early majority. The introduced product variety needs to be expanded gradually; and the product variety must cover the whole market, which includes a large variety of product preferences. For the late entry organizations, the organizations must select their targets whether the whole market or focused areas within the market. In order to identify the range of the target customers, it is necessary to analyze the product features, which are in the current products introduced by each organization.

In this research, two factors are used for this analysis (Fig.1). Each factor is analyzed for each organization in the market. In the growth stage, customer preferences change quickly. The amount of product variety is to follow this customer movement. The range of the product price indicates the width of the target customer groups, because the expected price level is different from each customer group.

Analysis of degree of product similarity

The product similarity of each organization is analyzed by the product characteristics of other organizations which exist in the same market. In the growth stage, the organizations can roughly be categorized into two types by each characteristic. One attains product differentiation by the other organizations and aims at establishment of the de-facto industry standard. The other introduces the products which are similar to popular models in the market, in order to reduce the market penetration mistake of the new products. Especially, the product line of similar products with small variety enables the introduction of low-priced products. However, it cannot correspond to a change in target customers during the entire product life cycle period.

Two factors are used to measure product similarity (Fig. 2). Product specification is used as a factor which judges products as a total system. Product function is used as a measurement factor of the practical usability of a product. Both factors are developed to observe the product similarity from the customer's viewpoint. This analysis method enables evaluation of both the internal and the external comprehensive level of product similarity.

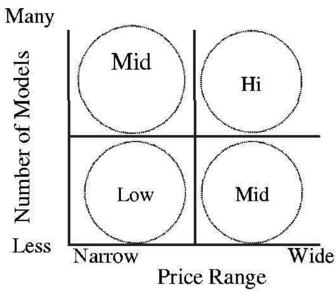

Fig.1 Analysis of Product Variety

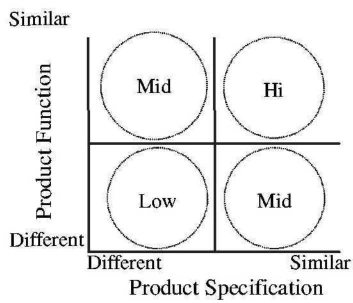

Fig.2 Analysis of Product Similarity

FOUR PRODUCT DEVELOPMENT STRATEGIES FOR GROWTH STAGE

During a growth stage, organizations must figure out clearly the target market and customers preferences. Because the speed of market growth is faster, organization need to track the target market characteristics change to adapt the customers' product requirements. The strategies are developed by focusing on two main points; the target customer types and the target customer size. The organizations with the selection of the each point define the competitive movements in growth stage.

In this research, these points are carefully considered to fit the current market characteristics and four types of new product development strategies are developed. The strategies are leader strategy, proactive challenger strategy, reactive challenger strategy, and follower strategy.

Leader strategy

The target customers of the organization which takes leader strategy are mostly late innovators, early adopters, and early majority. In the case at the beginning of growth stage, innovators and early majority is recognized as major customers. In this case, the organizations need to supply the products corresponding to product preferences of the customers in the new market. The customers in the early growth stage prefer newness and originalities of products. Supplying the new products which are with high technology or/and high level of originality are required to attract the customers in this period.

After the market condition moves into the late growth stage, other types of customers are identified as additional customer groups. The new customers have different product preferences from the customers of early growth stage. The additional customers prefer to select the new products carefully from the large variety of products. The organizations need to adapt the preferences of the new types of customer's.

The new products of the organizations with leader strategy require not only the high level of product variety but also new and high technology products and/or original products.

Proactive challenger strategy

The proactive challenger strategy focuses on the customer preference which is in the first half of growth stage. In this period in a product life cycle, the types of customer are categorized in innovators and early adopters. The both customer types have similar product preferences and are attracted by newness and originality of the product. In this condition, the organization taking proactive challenger strategy should produce the new products including new technology and originalities. The product differentiation for creating product originalities is developed by the analysis of products in the current market. The detailed market analysis helps to find the direction of new product concept.

The introducing distinctive products to the market leads the potential to take a de-fact industry standard, also. Offering the high quality products using different industry standard might attracts the customers especially who are in early growth stage. In addition publicity of new products are very important to overtake the most popular products in the target market.

The new products of the organizations with proactive challenger strategy require high technology and/or original unique ideas for the creation of distinctive product features.

Reactive challenger strategy

The organizations taking reactive challenger strategy introduce the new products after the target market is clearly identified by the early entry organizations. The major targets of the organization with this strategy are late early adopters and early majority. Both customer types are not high-risk takers and organization must satisfy the corresponding customers' requirements of high quality standard.

The target customers of the organizations taking reactive challenger strategy prefer selecting the products from large variety of products. The new product line for the target customer should be organized by large variety of products. In this case, the product variety is developed by the similar products of major products in the market. Introduction of similar products of higher sales products reduces the risk of market penetration mistake.

The new products of the organizations with reactive challenger strategy require high level of product variety and the products must be similar products of major products of current market. The reasonable priced products are also necessary, because the products are late introduced products with no product originality.

Follower strategy

Follower strategy aims at the one particular part of the target market during the last half of growth stage. The customer type in this period is mostly early majority. This customer type is very careful about product qualities and tends to buy only popular products which have good reputation in the market.

Follower strategy introduces the products to the some selected parts of market and the products should be very similar to popular products in the market. The produced products are already well known in the market and the speed of market penetration is easy and very fast. The large sales promotion is not necessary because the products are promoted by other organizations already.

The new products of the organizations with follower strategy require high level of product similarity and quality. The product variety is minimized to focus on only profitable customer target. The setting of adequate and precise customer target is required to succeed by this strategy.

STRATEGY CLASSIFICATION

After the analysis of the product variety, and the product similarity, the product development strategy is selected with consideration of each strategy concept, as shown in Fig.3.

Large number of product variety and low level of product similarity

In this case, leader strategy is suggested. The organization with these product characteristics has a good reputation as a de-facto standard in the market by early entry into the new market. In order to obtain or maintain a market leader in a market, the organization should supply continuously new products, which prevents easy market entry of following organizations. In this case, unique products with new technological features must be developed and introduced to the market continuously.

Large number of product variety and high level of product similarity

In this case, reactive challenger strategy is suggested. The purpose of an organization falling under this category is covering the whole market with the product containing the popular product functions which were previously introduced to the market by the early entry organizations. The product introduction with a large number of varieties is effective in obtaining the market share. A popular product model is selected quickly from the market, and organizations produce similar products only. This method reduces the possibility of sales failure.

Small number of product variety and low level of product similarity

The proactive challenger strategy is suggested for this section. The product introduction with small product variety focuses on a specific customer type. In addition, the product with a low level of product similarity assign innovators to one of the target customers. The introduction of this type of product has a potential to obtain the de-facto standard in a market.

Small number of product variety and high level of product similarity

The follower strategy is suggested for this section. This type of strategy does not aim at the acquisition of a de-facto standard since the market entry time is later than other organizations. The purpose of this strategy is to obtain certain returns of the new product introduction. Introducing products should be only similar products with small product variety. The introduced products must be the most popular products in the market.

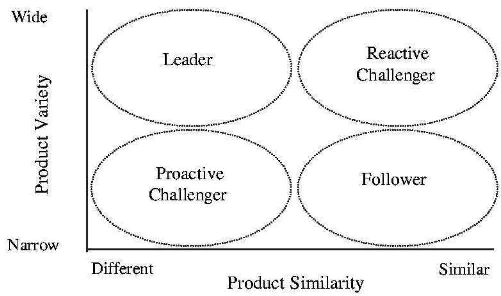

Fig.3 Product Development Strategies

CASE STUDY, THE PORTABLE MD PLAYER

The portable MD player is selected for the analysis of product similarity and variety. The primary reasons for the selection are that the market is in growth stage and technological innovations are the key to continuous sales growth. Three major research steps are included: (1) analysis of product variety (2) analysis of product similarity, and (3) classification in product development strategies.

RESULTS

The results of the classification and application in the correspondent product development strategies for organizations in the portable MD player industry are discussed in this section. The industry which is in the growth stage is selected to determine the reliability of strategy application.

Analysis of product variety

Analysis of product variety of the portable MD player industry is summarized in the Fig. 4. The point of price range on the x-axis and the point of product model number on the y-axis are plotted. Both data are 3-year data from 1997 to 1999. Each plot indicates conditions of product variety during the growth stage. For example, Sony indicates 1.57 point of number of models and 1.32 point of price range. Point 1.0 on the each axis indicates the average level in the sample market. The chart shows the difference of the organization's product variety level in the market. Only Sony has a higher level of product variety with a large variety in both price and product models. In addition, Sharp has a higher level, but it is with only a large variety of product models.

Analysis of product similarity

Analysis of product similarity of the portable MD player industry is summarized in the Fig. 5. The point of product specification on the x-axis and the point of product function on the y-axis are plotted. Both data are 3-year data from 1997 to 1999. Each plot indicates conditions of product similarity during the growth stage. Point 1.0 on the each axis indicates the average level in the sample market. The chart shows the difference of the organization's product similarity level in the market. For example, Panasonic and JVC have a higher level, but it is with only a high level of similarity of product function.

Classification in product development strategies

In the Fig. 6, the point of product similarity on the x-axis and point of product variety on y-axis are plotted. The location of each plot indicates the allocation of product development strategies. For example, Panasonic indicates 1.08 point of product similarity and 0.77 point of product variety. The point 1 on each axis indicates the average level of product variety and similarity in the sample market. The chart shows allocation of product development strategies. As explained in the previous section, the strategies are categorized by their level of product variety and product similarity in the market. In the chart, each section indicates the following strategies:

Section 1: Leader strategy
Section 2: Proactive challenger strategy
Section 3: Reactive challenger strategy
Section 4: Follower strategy

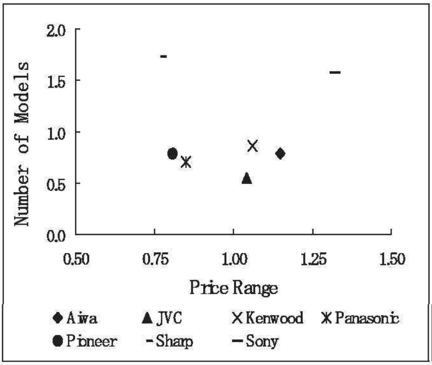

Fig.4 Analysis of Product Variety

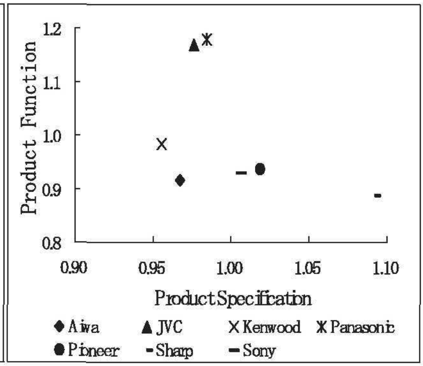

Fig.5 Analysis of Product Similarity

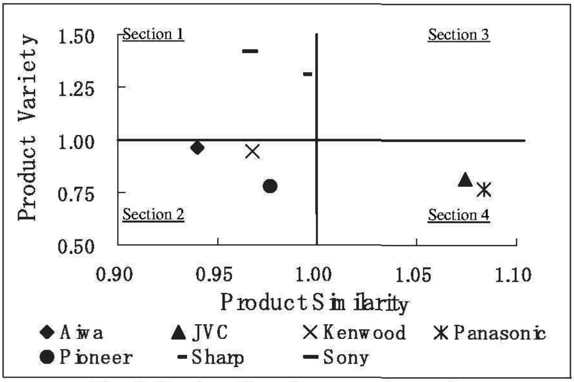

Fig.6 Product Development Strategies

For example, Sony and Sharp are categorized into organizations which fit into leader strategy, because they have a high level of product variety with less product similarity in the sample market. On the other hand, Panasonic and JVC which are categorized into follower strategy have high levels of product similarity with less product variety.

CONCLUSIONS AND RECOMMENDATIONS

In this section, the results are reviewed to identify an effective application method of the four types of product development strategies.

Review of product variety

Product variety is analyzed by two factors, the number of product models and price range. In the Fig. 4, the analysis of product variety, the organization with high level of product variety is Sony. Pioneer and Panasonic have low level of product variety. Pioneer and Panasonic introduce small variety of products. The other organizations have average level of product variety.

Review of product similarity

Product similarity is analyzed by two factors, similarities of product function and specification (Fig.5). In the figure of the analysis of product similarity, organizations with higher level of product similarity are Panasonic, JVC, and Sharp. Aiwa and Kenwood are categorized as an organization holding lower level of product similarity. The other organizations have mid level of product similarities.

Review of classification of product development strategies

Classification of product development strategies is analyzed by two factors, product similarity and variety. As shown in Fig. 6, leader strategy is fit to Sony and Sharp. Both have the possibility to take the market leader. Aiwa, Kenwood, and Pioneer are categorized under proactive challenger strategy. They produce small variety with less similarity products for focusing on the specialized customers who are satisfied by their original products. Panasonic and JVC take follower strategy, because of a low level in product variety and a high level in product similarity. They produce similar products and have a smaller risk of a new product launch failure.

SUMMARY

Strategies are categorized into four types, leader strategy, proactive challenger strategy, reactive challenger strategy, and follower strategy. The strategies are selected by each organization's level of product similarity and variety in the market. Organization with high level of product variety and low level of product similarity is suited for leader strategy. In the case where both levels are low, it is classified into proactive challenger strategy. High levels of product similarity with low levels of product variety are classified into follower strategy. Organization with high levels of both is suited for reactive challenger strategy.

The portable MD player industry is selected as a sample market to apply this analysis and strategy. The organizations in the market are ranked by the level of product similarity and variety. After analysis of both factors, each organization is classified into four types of strategies. The strategies suggest the next move of product development management by following the market and product characteristics of each organization. This method is effective as the product development management tool for a growing market.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
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19

ESTABLISHING A PRACTICAL COMPANY INNOVATIVE BENCHMARK

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INTRODUCTION

Innovation is a major driving force for the economic growth and expansion of companies. The globalisation of markets has raised strong competitive pressures. The rapid evolving technology, the fast changing markets and the more demanding customers, require developing high quality new products more efficiently and effectively. Taken that every firm can be represented as a bundle of resources, skills and competencies (Neel and Hii 1998), the effect of innovation is to transform a firm's inner capabilities, making it more adaptive, better able to learn, to exploit new ideas. This need to innovate has become clear by now. One of the latest European Union Innovation policy studies reported that over half of all the European enterprises (51%) are technological innovators (Cordis 2000). Furthermore In the European Union, new products or services renewed within the years 2000-2001, account on average for approximately one fifth (20.4%) of companies' turnover. Two companies out of every three introduced new products and services over this period and almost 12% of companies can be considered highly innovative, with over half their turnover generated by new products. (Cordis 2001).

Small and Medium Enterprises (SMEs), have shorter lines of communication, relatively informal decision making and more flexibility, which seems to give them an advantage for rapid innovation over large co operations. Surprisingly, the Community Innovation Survey 2 (CIS2) showed the complete opposite results. Overall, the larger the firm, the more likely it is to be an innovator (Figure 1). On average across the EU, innovations were introduced by 79% from large manufacturing firms (those with more than 250 employees), by 58% from mediumsized ones (50-249 employees) and by just 44% of small ones (fewer than 50 employees). In the service sector, the corresponding figures were 73% for large, 49% for medium and 37% for small firms. Sales of innovative products as a proportion of total turnover increase with firm size – from 15% for small firms to 21% for medium-sized and 38% for large ones. Small and medium-sized enterprises account for 29% of Europe's total manufacturing sales, but for only 18% of sales of innovative products.

Large companies have responded early to the need of management of innovation. This was the only way to be competitive and remain in business, since most of those who failed to realise this need, didn't survived. They have examined themselves and in doing so have created a range of tools and techniques to help them adapt to changed circumstances and meet new market challenges. SME's on the other hand, even if they are very well aware of the importance of innovation have been rather slow in adopting these tools and techniques, which often are very difficult or even impossible to be applied to them. There is certainly no shortage of product ideas and concepts flowing within SMEs. However, in a large number of cases, there exists an inability to bring successful innovations to the marketplace in a controlled and coordinated way. Vision and drive are not enough for successful on-going product developments. A large number of studies over the past decade have indicated that SMEs frequently suffer in the management of their product innovation process through a lack of structure (Jones et al 2001). Constantly successful innovation requires discipline, good teamwork and the careful assessment of progress at each phase.

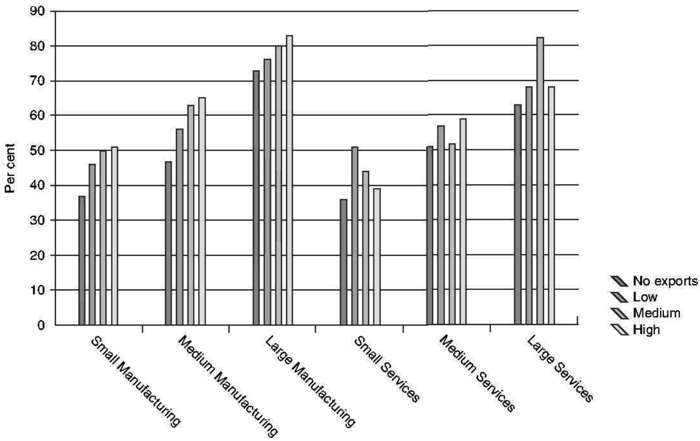

Figure 1: Number of innovators by export intensity, breakdown by size class, EEA, 1996, Source: CIS2, Eurostat/Enterprise DG

This paper presents a practical tool for improving innovative performance of SME, by measuring innovation and determining a product innovation register. We propose a methodology for establishing a range of industry standard Innovation scores called PIP-SCORES (Product Innovation Profile scores -or innovation benchmarks) for a range of SMEs in industrial sectors that include creative industries, electrical/electronic, fire and safety, footwear, plastics, ceramics and textiles. In addition, the PIP SCOREs can be correlated across a range of SME topologies and industries. Our aim is to contribute to improved benchmarking of European Union product developers who wish to monitor their prowess in terms of innovation and re-use the methodology to review position post any intervention to improve inherent innovation.

In the first part of this paper, the most commonly used measures of Innovation are presented, and the difficulties in applying them to SMEs are described. Next, we tackle the Innovation survey approaches and the use of Benchmarking always from the SMEs point of view. In the second part we present our methodology, which is a combination of measuring innovation, through an innovation survey and determining a score of innovativeness for benchmarking. Our key aspect of our approach is that it can be easy and very practical be applied to SMEs.

PART I – MEASURING INNOVATION

Common Measures of Innovation

Since the importance of innovation in SME's is by now very clear, one major issue is how can we measure innovation? Many studies have focused in this issue, but the measurement of innovation is still clouded with statistical and conceptual problems (Neel and Hii 1998). Danneels and Kleinschmidt (2001) conclude that prior research on innovation measurement has not clearly distinguished between newness as unfamiliarity, as lacking fit with existing competences, or as implying new types of activity. The main problems in measuring innovation are the lack of correspondence between the economic significance on the one hand and the scientific and technological significance on the other hand. Furthermore it is difficult to identify a relationship between resources devoted to certain scientific and technological projects and their economic returns (Archibugi and Sirilli 2000).

Since now the most commonly used measures of innovative activities are: R&D expenditures, patent counts and counts of major or minor innovations, but the task of applying these measures to SME's has many difficulties and may result to misleading conclusions.

R&D data are usually collected in the OECD economies according to the procedures and categories described in the "Frascati Manual" (OECD 1980). R&D statistics do not cover all aspects of technological change. It has been stressed that they underestimate the innovative potential of small and medium sized firms, which seldom have formal R&D laboratories (Acs and Audretsch, 1991). R&D numbers measure only an input, which has no necessary relation to innovation outcomes. There are many examples of successful innovating SME's which perform relatively little R&D.

Patent data can be retrieved in the records of US Patent Office and the European Patent Office. The weaknesses of patent measuring are that each country has a different patent legislation, not all inventions are patent or patentable and patents do not necessary represent a commercially exploited innovation (Archibugi and Sirilli 2000). A recent EU Innovation policy study for enforcing small firms' patent rights (Cordis 2000) confirms fears that the current patent system works poorly for SMEs. The study showed that the two-thirds of the firms had experienced attempts to copy their patented inventions, but only one in five actually used the courts to defend their patents. For

SME's, patenting is currently not cost effective as a means of protecting intellectual property making the patent measuring unreliable for SME's.

Survey Approaches For Measuring Innovation

There is a huge increase in the usage of innovation surveys during the last years. Innovation surveys can be used as tools to analyse the innovative activities, assessing innovation of firms and explore their practices (Brusoni et al 1998). In general there are two approaches to collect innovation data.

The first approach is the object approach and collects information on the level of individual innovation i.e. information on the output of the innovation process. This approach may have the advantage of representing a direct measure of innovation due to that only the significant innovations are recorded, but it is very difficult to develop comparable databases internationally.

The second approach, the subject approach, collects information at the level of the firm, i.e. information on the input of the innovation process and can cover this way a wider range of issues. It can record information on the impact of innovation, on successful and unsuccessful innovative activities in innovating and non-innovating firms. This method usually utilises questionnaires or direct interviews. Although self-assessment measures may be prone to bias, they are the most commonly used form of performance assessment because the presumably more objective accounting measures and sources can also be biased. (Gatignon et al 2002). Furthermore these perceptual measures have been shown to be reliable (Doyle et al. 1989).

Basic guiding lines for developing an innovation survey are included in the Oslo Manual (OECD 1994, 1997). The manual recommends the subject approach to use when conducting innovation surveys and since then this approach has become dominant. The methodology suggested in the manual was used by Eurostat and the European Innovation Monitoring System within the European Commission, which since now has implemented three Community Innovation Surveys (CIS1: 1994-1995, CIS2 1999-2000 and CIS 3 started in 2001).

Surveys based on the Oslo Manual tend to be quite long, and require considerable resources within a firm to complete (Holbrook and Hughes 1997) and this becomes a bigger problem if the surveyed company is a SME. Most such surveys are conducted under the terms of national statistics legislation, which generally contain legal provisions requiring the respondent complete and return the questionnaire. Other surveys usually have poor response rates as firms tire of the long lists of questions. Respondents do not yet have a consistent understanding of the concept of innovation, which varies form one industrial sector to the other (Guellec 2001). One basic outcome of the Oslo Manual is that innovation is problematic to define precisely. In practice survey research must be based in a relatively short definition and accept the fact that the respondents will use varying interpretations (Rogers 1998). The questionnaire design in crucial for the quality of the data collected.

Benchmarking

Benchmarking is a method for comparing firms. Benchmarking provides to a firm a useful tool for allowing them to compare their performance relative to an average or to other firms. Benchmarking is a continuous process. According to the Oslo manual benchmarking leads to better understanding of the organisation's current practices, and makes use of systematic comparison of practices and performance with those of others to develop improvement actions, which will bring performance levels up to or beyond those of the 'best in class'.

Despite benchmarking has become very popular in successful firms it remains a relatively underused tool in the field of innovation (Pervaiz and Zairi 1999). A vast number of studies identified success or failure factors in product development, but few have tried to incorporate innovation to performance benchmarking. As an exception we can refer Coopers studies (Arleth and Cooper 2001, Cooper and Edgett 2002) who present on a benchmarking to identify critical success factors that set successful companies apart from the not so successful ones.

One main feature that appears in benchmarking and related studies within the innovation is the bias towards quantitative definition of best practices rather than softer definition. Some researchers try to illustrate the need to break away from sole reliance on hard metrics of benchmarking measurement to a soft metrics or to more balanced use of soft and hard metrics (Pervaiz and Zairi 1999). In order to apply benchmarking to SME,s the methodology should be short and clearly defined.

PART 2 - THE PIP-SCORE APPROACH

All initiatives on improving the innovation within the organization in the past, have addressed ways of improving the product innovation process, through a wide spectrum of methods, techniques and tools without quantifying the degree of change of "innovativeness". This paper presents a methodology based on the 'pip score' process, which is used to position an organization in terms of its level of product innovation maturity.

The Three Axes of Innovation

According to the EU Green Paper on Innovation, innovation is:

- the renewal and enlargement of the range of products and services and the associated markets;
- the establishment of new methods of production, supply and distribution;
- the introduction of changes in management, work organisation, and the working conditions and skills of the workforce" EC(1995:2).

Product Innovation occurs when a new or improved product is introduced to the market. Process innovation is an adoption of new ways of making products or services. The innovation process is the combination of activities - such as market research, communication, design, process development, organisational restructuring, and so on - which are necessary to develop and support an innovative product. There is a strong correlation between product innovation and process innovation. Process innovation may result in product innovation and similarly, product innovation may force process innovation. Organizational innovation follows these two dimensions. Since now innovation surveys discount the importance of role of organisation in innovation. They focus instead on the process of technology acquisition and sources of information for innovation (Brusoni et al 1998). Recent studies also emphasises the need to broaden the concept of innovation, ie., should organisational change be included? (Klomp 2001).

Since now there are no initiatives or schemes, which have addressed all three dimensions, in a holistic approach to a company innovation and attempted to resolve them in order to determine their independency. Not in any case has the emphasis of the research been placed on 'what is the value, level of the innovation within an organisation considering their products, innovation process and project management of the process?' (Bilalis et al 2002).

The pip-score approach the addresses three interrelated, but separately measurable dimensions of innovation in a company:

- The product axis
- The process axis
- The management or organizational axis.

There are ten attributes for each axis. There is a strong correlation between the three attributes of each row (Table 1).

The range for each attribute is between 0 and 4 having discrete fraction of 0.1. By resolving the above three axes values you acquire a PIP SCORE. This value represents the "innovationness" of the company in a specific sector (figure 2).

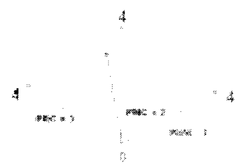

Figure 2. The product innovation profile score concept

Table 1: The ten innovation attributes of each dimension

	Product Dimension		**Process Dimension**		**Management Dimension**
1.	Market need	⇔	Market appraisal	⇔	Focus on feasibility studies
2.	Easy appeal to target groups	⇔	Liaise with target groups	⇔	Formal procedures to ensure dialogue with target groups
3.	Best use of technology	⇔	Technology access	⇔	Formal procedures for evaluating best use of technology
4.	Value for money	⇔	Value and cost analysis	⇔	Costing controls
5.	Standards compliance	⇔	Compliance investigation	⇔	Quality control procedures for standards compliance
6.	Original/novel solution	⇔	Idea generation technique	⇔	Maintenance of culture to ensure original/novel solution
7.	Offers improvements	⇔	Active attempts for improvement	⇔	Measurable tests to determine improvement
8.	Delivers functional needs	⇔	Processes for delivering functional needs	⇔	Measurable tests to ensure functional needs
9.	Good aesthetic definition	⇔	Design emphasis on good aesthetic definition	⇔	Marketing and quality control procedures to determine good aesthetic definition
10.	Complies with IPR	⇔	Procedures to ensure no breach of IPR	⇔	Legal process control

Scoring on these 3 axes is at the heart of creating a replicable innovation register and benchmark. The approach itself focuses on using non-intrusive assessment and diagnostics methods and techniques to examine the organization and determine their level of innovation in respect of product and/or service development. The company's current "position" is then evident together with the capability to set targets whereby the enterprise can improve such a score / profile and benefit from this initiative. Previous experience, piloting such techniques, indicates it is possible to offer a very fast track process - 2-3 days - to determine the register. Designing a framework for improvement of this scoring (ie. the targets) can be achieved within a single day (or less). An average three months period to implement changes and re-orientate the culture is followed by a re-test of the PIP scoring process to achieve a measure of change against the original register and benchmark. On average, significant changes (for the better) can be achieved within four months; with a climate shift in terms of continuous improvement in approximately 6-9 months (Jones et al 2001).

The Methodology and Its Support

The approach methodology consists of 3 stages. The first stage is the hello process. This process aims at introducing the PIP-SCORE methodology to the interested company. It combines all conventional approaches, ie: telephone or e-mail contact, hardcopy and CD-ROM distribution through post mail and access to a secure area of the PIP-SCORE website. The hello material includes an introduction to the PIP-SCORE process, FAQs, case study examples of companies who have used the PIP-SCORE assessment and a slideshow describing the PIP-SCORE concept in more detail.

The second stage is a Quick and Easy (Q&E) Assessment of PIP-SCORE. This can be applied directly on the web site, or through completing a hardcopy version and returning same to a nominated facilitator. The result of the Q&E Assessment identifies scores relating to product, process and management and a total score that reflects their position in the all three areas, showing the company's product innovation profile as a PIP Score. This process should take a few minutes (optimum 10).

The final stage includes and an Analysis and Verification of the PIP-SCORE. The SME user undertakes a more in-depth PIP SCORE process using the CD ROM (Toolikit) for guidance. The registered user will have access to technical support available through face to face meetings, telephone, web Chat and/or e-mail contact. An important part of the process is the contact with the technical intermediary who can act as a mediator (or outsider) when establishing the benchmark for company. This purpose of the contact is to provide the company with all the necessary assistance and support material, in order to improve its scoring.

Its operation is supported through a web site, the www.pip-score.org including:

- Pip-score news
- Guidance to the methodology including pip-score fundamentals, facts and FAQs
- Media items, related to pip-score, including: conferences and papers, pip-score workshops, media coverage, announcements and awareness sessions.
- Support material
- A product gallery and on-line polls for obtaining pip-scores for the listed products
- Pip-score discussion forum
- Members area including: access to private messages, downloadable documents, contacts list, events list and polls
- On line project management for the project

Example – The Innovation Profile of the creative industries sector

By participating in the PIP-SCORE survey, each company provides information about its sector, size and type of product. One of the sectors which is included in our innovation survey, is the creative industries sector, which includes software, internet developer, network design, craft and fashion design companies. During the first stage of our methodology we obtained data from 100 companies from this sector and included them in our database. Now, every new firm coming from the same sector and wishes to participate in the PIP-SCORE Survey, can be benchmarked with the average scores of the innovation attributes of the sector. The results indicate areas of acceptance and possible corrective actions. (Table 2). In this table we present the Innovation Profile of the sector (average scores) and the example of Benchmarking the Innovativeness of an SME in the sector, with the sector averages.

CONCLUSIONS

Having applied this process to a number of SME end users in various sectors the results indicated that the principles were sound and that the approach had great value because:

- An initial innovation register and profile is obtained

- A degree of change can be measured after intervention(s) (ie. implementation of attribute or property) against the original register and profile
- Registers can be established for companies of similar topologies and sectors and can be characterised as benchmarks for best practice
- Models or roadmaps for improving an organisation's innovation can be documented with a view to recycling some for use in other European Union SMEs. Such models or roadmaps are best practice routes to innovation improvement.

Evidence from previous project work indicates that there is justification for the approach in determining a PIP SCORE for a company. The associated benefits are that proposed interventions of any established kind can be supported by a measuring process to determine amount of change (improvement or otherwise). Importantly, when the results of the PIP SCORE are realised at the conclusion there will be benchmarks for SMEs in specific sectors that will indicate optimum position for an SME of similar topology and defined attributes or properties that an SME has to have in place to reach that position. The results will also make available case study materials that will indicate the methods applied for SMEs to acquire such a scoring.

On the long term the Scientific/Technological objectives are:

- To establish a range of industry standard PIP SCOREs (or innovation benchmarks) for a range of SMEs in industrial sectors that include ceramics, electrical/electronic, fire and safety, footwear and creative industries. In addition, the PIP SCOREs will be correlated across a range of SME topologies and industries. Clearly defined matrices for each axis will support the PIP SCOREs ie. Product, process and management
- To develop a proven and documented methodology, with support tools on CD ROM, that can be replicated in SME product developers in all other industrial sectors in the European Union. The CD ROM will be supported by a functional

Table 2: Benchmarking the innovativeness of a SME from the industrial industries sector

	Product Dimension Attributes	Score	Average	Action	Process Dimension Attributes	Score	Average	Action	Management Dimension Attributes	Score	Average	Action
1	market need	**4**	2,6		Market appraisal	**3**	1,2		Focus on feasibility studies	**2**	1,8	
2	appeal to target groups	**3**	2,2		Liaise with target groups	**2**	2,1		Formal procedures to ensure dialogue with target groups	**2**	1,9	
3	Best use of technology	**2**	2,1		Technology access	**2**	2,3		Formal procedures for evaluating best use of technology	**1**	1,7	
4	Value for money	**2**	2,0		Value and cost analysis	**1**	1,9		Costing controls	**1**	1,2	
5	Standards compliance	**3**	3,2		Compliance investigation	**3**	2,1		Quality control procedures for standards compliance	**2**	1,8	
6	Original/novel solution	**2**	2,9		Idea generation technique	**1**	1,8		Maintenance of culture to ensure original/novel solution	**2**	1,7	
7	Offers improvements	**3**	2,8		Active attempts for improvement	**3**	2,0		Measurable tests to determine improvement	**2**	1,9	
8	Delivers functional needs	**3**	3,8		Processes for delivering functional needs	**3**	2,8		Measurable tests to ensure functional needs	**2**	2,0	
9	Good aesthetic definition	**4**	2,5		Design emphasis on good aesthetic definition	**3**	1,6		Marketing and quality control procedures to determine good aesthetic definition	**3**	1,4	
10	Complies with IPR	**2**	2,2		Procedures to ensure no breach of IPR	**2**	1,8		Legal process control	**2**	1,1	
	Product Innovation Score	**2.8**	2,6		**Process Innovation Score**	**2.3**	2,0		**Management Innovation Score**	**1.9**	1,7	

Above average sector score (>average+0.5): **no action need**

Sample: 100 creative industries sector – software, internet

● Close to average sector score(average ± 0.5) **possible corrective action required**	developer, network design, craft and fashion design companies
● Below average sector score (average -0.5), **corrective action required**	

- website which will add to the self perpetuating innovation qualities of the project whereby users will use the site for reference, updates, communication with support team and each other and a database of PIP SCOREs
- To contribute to improved benchmarking of European Union product developers who wish to monitor their prowess in terms of innovation and re-use the methodology to review position post any intervention to improve inherent innovation in terms of process, product and/or management
- To train and support SMEs in the use of the methodology and establish PIP Scores and corresponding PIP matrices. Each SME will develop an individual case story, which will be published in technical and non-technical formats. Scores from the SMEs will be correlated for individual sectors and cross sectors.

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20

INFORMATION TECHNOLOGY AND ORGANIZATIONAL FACTORS IN CUSTOMER SERVICE MANAGEMENT: A MULTIPLE CASE STUDY IN BRAZIL

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INTRODUCTION

During the 1990s, the number of Customer Service departments in operation in Brazil grew by around twentyfold, today reaching several thousand. Currently these services receive many thousands of contacts per day, ranging from simple suggestions and complaints to requests for information, praise or criticism. In some companies, consumer communication is treated "strategically". It is used as a tool in customer relationship management and becomes a source of information for decision-making. In others, Customer Service still acts, basically, as a screen for client communication, being limited to clarifying doubts and answering complaints.

The research on which this paper is based investigated the experiences of four companies: two from the food industry and two from the pharmaceutical sector. Its purpose was to identify the factors which favor or inhibit the use, by different levels and sectors of an organization, of the information received by Customer Service.

LITTERATURE REVIEW

Customer Service is capable of bringing the following advantages to a company:

- In terms of image: it explicitly offers the client an additional service, which provides greater security and transmits the idea that the company is interested in hearing and serving its customers. Mathieu (1998, p. 73) highlights that after-sale service, in general, can "be understood as a purchase criterion to the extent that it represents a reduced factor of risk for the consumer". Zülzke (1997) also points out aspects of security transmitted by these consumer services.
- In terms of retention of clients: Customer Service allows dissatisfied or disappointed clients to communicate with the company, which can contribute to reduce the so-called silent exit (Stephen e Gwinners, 1998) and minimize the occurrence of other potentially harmful actions, such as legal proceedings, recourse to the press and negative word-of-mouth. According to Reichheld (1996, p.56), "a climbing defection rate is a sure predictor of a diminishing flow of cash from customers to the company – even if the company replaces the lost customers". In addition to this, several studies have shown that the satisfactory resolution of an unsatisfactory episode tends to create trust and customer commitment to the company. (Tax; Brown and Chandrashekaran, 1998; Urdan and Zuñiga, 2001), as well as positive word-of-mouth, which can be even greater than that which occurs in the case of satisfactory purchases (Swanson and Kelley, 2001).
- In terms of relationship marketing: as well as avoiding customer defection, Customer Service is also a powerful instrument, which can be used pro-actively in promoting loyalty. Using databases built on customer communication, many companies, such as Nestlé, Danone and O Boticário have developed successful programs and managed to establish regular and personalized relations with hundreds of thousands of customers (*Guia Brasileiro do SAC*, 2002).
- In terms of a source of learning, transformation and innovation for the organization: Zülzke (1991, p. 71) observes that complaints are "elements instigating changes and growth in organizations". Reichheld (1996, p. 58) states that the lost clients "are always the first to know when a company's value proposition is foundering in the face of competition". The opening of a channel of communication, as well as

avoiding customer defection, allows their intentions and opinions to be captured. According to Reichheld (1996, p. 64): "customer defection is a unit of error containing nearly all the information a company needs to compete, profit and grow". Barlow and Moller (1996, p. 32) also state that "customer complaints inform the companies how to improve services and products - and therefore help to maintain market share." They add: "in many cases, the information that a company obtains through complaints is impossible to obtain from any other source" (p. 34). Lastly, Mitchell (1993, p. 24) highlights the fact that Customer Service has the advantage of allowing information from the customers to circulate within the company, reaching areas with little or no client contact, which "helps in the strategic task of making the whole company more responsive to customer needs".

While they can, theoretically, offer all of these advantages, Customer Service does not always bring all these benefits to the companies which implement it. Litterature on the subject basically points to two reasons for this: the frequently marginal position reserved for these sectors in the organization structure and the inability of the companies to register, process and distribute the information received.

- Concerning the position occupied by Customer Service within the organization, Zülzke (1997, p. 7) notes that these sectors bring consumer issues inside the companies and that this, in some way, goes against the usual order of the organizations, where "power is exercised from top to bottom". Lancioni (1995, p. 22) also mentions the risk of being "at the mercy of middle management groups who frequently regard customer service as a hindrance, rather than an asset". In order to deal with these difficulties both authors recommend direct subordination to top-level administration. This position, by formally ratifying the importance of the mission given to Customer Service and giving it a greater capacity to move freely inside the different departments of the company, would help it to overcome the resistance commonly met by the activities of the sector. Singh and Wilkes (1996) and Tax and Brown (1998) also highlight the crucial importance of empowerment to the effective functioning of these services.
- Regarding the registration, treatment and distribution of data, Tax and Brown (1998, p. 8), observe that many companies "fail to document and categorize complaints" and appear "to have no systematic way to collect and distribute complaint information to the individuals responsible for the process that failed". The authors highlight the role of technological support in this task. They cite Ford, as an example, which distributes, via electronic means, communication received by Customer Service to those responsible for resolving the problem, also distributing it

to the market research and engineering departments which integrate the data to information obtained through research.

Mitchell (1993, p. 26) also underlines the importance of a "comprehensive computerized complaints handling system", which allows customized treatment, of both individuals or groups, easily and quickly. According to the author, the absence of adequate technology means that companies spend 95% of the time reacting to individual requests and less than 5% analyzing communication and responding efficiently. Jones (2000) notes that the first advantage provided by the technology is to facilitate consumer access to the organization. In addition to this, he highlights the fact that, ultimately, the performance of these sectors is related to two factors: the technology employed and the training of the staff.

OBJECTIVES AND METHODOLOGY

The aim of the research was to investigate the factors which favor or inhibit the use by companies of communication received by Customer Service departments. In order to obtain a more wide-ranging and detailed understanding of the problem, the case study method was chosen. To this purpose, companies were chosen in which Customer Service occupies different positions: two in which the sector was directly responsible to top-level management and two in which it was subordinated to a tactical-operational sector.

In each of the companies studied, the following information was sought:

- Historical and attributions of Customer Service: motives for creation, mission, and activities;
- The position and composition of Customer Service: position in the company structure, number of staff, their background and training;
- The system of registering and dealing with customer communication: technology used, procedures, flowcharts, issuing and distribution of reports;
- The relations of Customer Service with other sectors: participation in meetings and decision-making processes;
- Modifications to products and processes as a result of consumer communication.
- The research was of an exploratory nature. Its results were designed to supply guidelines for new investigations and should not be used as generalizations.

RESULTS

Companies A and B belong to the pharmaceutical sector. Companies C and D operate in the food industry. All are large-scale companies and have been operating for various years in the country, where they occupy leading positions in their area.

Historical, Mission and Customer Service Attributions

Until 1998, company A had a conventional telephone line as its channel of communication with customers. Attendance was carried out by one person who had other additional tasks to perform. Consequently, there were customer-company communication difficulties, which generated many complaints. Another problem was the lack of a systematized way of registering and dealing with the communication received. Customer Service was officially created in September 2000. The aim was to facilitate customer relations. The sector supervisor records: *"The proposal put to me was that Customer Service would not only be a sector to answer complaints. It was not going to be just a facade, a place where dirt is swept under the carpet. The idea given to me was Customer Service where one spoke of CRM (Customer Relationship Management)."*

Company B's Customer Service was founded in 1997. Until then, the company had a communication channel dedicated exclusively to doctors. This restriction generated problems for the company. Consumers sent doubts, suggestions and even praise via post, but the company had difficulty in responding. This was due, principally, to the disperse nature of consumer contacts in the company. There was no area which centralized the capture of communication and responses to consumer questions: *"We had many complaints, we needed to identify the reasons and consequently the actions to be taken to avoid this negative image which was having an impact on the market, and by so doing improve our external image."* (Customer Service supervisor).

At company C, the process of interaction with consumers began in 1995 with the installation of an attendance point for customers which did not yet have the characteristics of Customer Service. According to the statement of one employee who was responsible for registering telephone contacts, *"It was the employee who decided how to attend the call and what should be asked, getting a piece of paper and putting: name of contact, address, telephone and reasons for the call"*. The more structured implementation of Customer Service was a board decision, which occurred in 1998. According to the manager, *"the board decided to create Customer Service after seeing* *the need for direct contact with our customers, (...) to obtain information about what the customer thinks of the company and to allow us to improve our products. Complaints, praises, suggestions, anything which makes company-customer relations closer".* According to the manager, *"the mission of Customer Service is to note everything that the customer says on a form and treat the customer with all due respect. To inform that all steps will be taken and to give a response in the future."*

The justification presented by company D for the creation of Customer Service was the establishing of the Consumer Defense Code. According to the manager: " *Customer Service had its beginning in the enactment of the Consumer Defense Code* [in 1990], *because the company was accompanying the evolution of what the market itself was asking for. (...) So Customer Service was founded bureaucratically to comply with a regulation. It wasn't that the Code obliged one to have a Customer Service department, but it stated that means must be created to allow customers to have access to the company."* The mission of Customer Service at company D is to protect the image of the products and the organization itself. As the manager relates: " *Customer Service receives valuable information on products and processes, allowing the company to guarantee the integrity of its image and its products".*

Position and Composition of Customer Service

At company A, Customer Service is responsible to a tactical-operational area (administrative sales management), which reports to the Marketing and Sales Operational Management which, in turn, reports to the Director of Sales, who is responsible to the President.

At company B, the sector is responsible to the Medical Director who reports directly to the President of the company.

At company C, Customer Service is responsible to the accountant. This function, though, is not solely related to customer service. In addition to Customer Service, responsibilities include other administrative and financial tasks which take up around 70% of the time. The accountant is responsible to the Commercial director of the company, whose immediate superior is the President of the company.

At company D, Customer Service is a sector in Consumer Services Management, which also administrates press relations. The Consumer Services Management is linked to the Marketing Service Management, which in turn reports to the Vice-president of Marketing, who is responsible to the President.

With the exception of company C, where all, including the manager, have a second grade education, all the Customer Service departments are led by graduate professionals who have staff members in their teams who are graduates in diverse areas. At company B, two of the staff are pharmacy graduates. At company D, one is a nutrition graduate, the other a law graduate. Company C is also the only company not to have training activities. In addition to regular training, company D prepared an Integration Program, in which visits to company factories are organized. During these visits, the Customer Service staff are given presentations on production units and techniques and give lectures on the activities in their sector. These visits aim to promote both technical knowledge and personal contact between Customer Service staff and those people who might, in the future, be affected by complaints.

Table 1: Position and Composition of the Customer Service Departments

	COMPANY A	COMPANY B	COMPANY C	COMPANY D
Number of levels between Customer Service and President	3	1	1	2
Composition of sector	7 staff (one supervisor and 6 analysts)	10 staff (1 supervisor plus 5 attendants and 4 trainees).	3 staff (Manager and staff with second grade education)	5 staff (1 manager plus 4 attendants)
Training	Yes	Yes	No	Yes

Registration, Treatment and Distribution of Communication Received

With the exception of company C, all the Customer Service departments studied use the software *Plusoft*, which allows the insertion and classification of diverse contact data (telephone and address of the consumer, reason for call, contact history, etc.) and makes possible the generation of statistical reports with differing degrees of detail. At company C, communication is registered on a form prepared by the sector and sent to the Commercial Director, who decides on what path to take. Once the process has been finished, they are returned to the Customer Service manager who files them.

As regards the treatment of communication, companies B and D have flowcharts which determine the route to be followed by the information, the action to be taken in each area, correspondence and reports to be issued and their addressees (internal and external). With the exception of company C, all the companies researched defined emergency procedures in case of health risks. Companies B and D delegate greater autonomy to Customer Service staff, who can interact with other departments without going through superiors. It is worth remembering that both contain staff in their teams, whose background is compatible with this responsibility (pharmacy in the case of company B, nutrition and law in the case of company D).

Concerning the issuing of reports, the resources and procedures at companies A, B and D are similar. All use the same software and regularly issue statistical reports directed to other areas. Customer Service at company C only issues reports when asked to by the Commercial Director of the company.

Lastly, Customer Service at companies B and D have their own media to communicate with the rest of the company. Customer Service at company B publishes an internal bulletin whose purpose is "to keep collaborators informed of improvements, changes and innovations in company products and services." (editorial of the first issue). This bulletin is widely distributed inside the company to different hierarchical levels, including the company representatives, who operate in the front line and are in direct contact with doctors and pharmacists. Customer Service at companies B and D have a space on the Intranet to publicize their activities and communicate with other sectors.

Table 2: Registration, Treatment and Distribution of Communication Received

	COMPANY A	COMPANY B	COMPANY C	COMPANY D
Registration System	*Software Plusoft.*	*Software Plusoft*	Own system (without connection to the company network)	*Software Plusoft*
Procedures	Sending of requests to areas via e-mail, telephone or in person.	Defined by internal flowchart.	Requests passed on to Commercial Director who actions the areas affected.	Defined by internal flowchart.
Reports	Regular to technical and administrative directors and President; on request to other areas.	Regular to Medical Director; on request to other areas; Information Bulletin and Intranet.	No set schedule, sent to Commercial Director and then filed.	Detailed monthly reports published via Intranet (all employees have access).

Relations of Customer Service with Other Sectors

The Customer Service departments at companies B and D interact regularly with other sectors, through direct contact in answering client communication and periodical or occasional meetings. According to the evaluation of employees at company B, *"today, people see Customer Service as a crystal ball, the 'all-knowing' part of the company. When they have any doubt, they call here"*. Customer Service at companies D is also consulted by other sectors and by the company's top-level management. At companies A and C, however, interaction with other sectors and especially with top-level management is rare. Customer Service does not participate in strategic meetings, and is not usually consulted in decision-making processes. For example, no Customer Service representative from company A was invited to participate in a seminar organized to discuss company strategy for the year 2001. At company C, Customer Service staff do not have direct contact with other sectors.

As regards the relations of Customer Service with other sectors, with the exception of company C, all the companies studied mentioned some instances of resistance. Company A recorded various cases of lack of co-operation, overcome thanks to the intervention of the president of the company, at the personal request of the Customer Service supervisor. At companies B and D, action has been taken to make other sectors aware of the activities carried out by Customer Service (an internal bulletin at company B and an Integration Program at company D). These initiatives seem to have brought positive results. At company B, team feeling is that resistance to Customer Service activity is diminishing. At company D, the staff gives credit to the Integration Program for the absence of conflict and the quality of relations with the other sectors.

Finally, at company C, the lack of direct interaction between the members of the sector and the rest of the company means there are no conflicts. The Commercial Director uses his authority, when necessary, to action other departments.

Use of Communication Received

All the companies researched tell of communication received which gave rise to studies and/or actions to modify products or processes. At company A, two packaging modifications are being studied. Until now, none has been implemented. One relates to a seal that was causing leaks in a medicine bottle. At company B, two modifications of products have been carried out (on the anti-counterfeiting "mark" on the packaging and in the manufacturing process of the pill strips of a certain product). In addition to this, the request from a consumer who suffered from a rare type of leukemia gave rise to the participation of the Brazilian subsidiary in an international test program for a new treatment. At company C, customer communication about nylon threads in biscuits led to the remodeling of the conveyor belt at a factory. An instruction was also given to employees engaged in delivery of merchandise to distributors to handle the packages with greater care as they were arriving damaged. Finally, at company D, the modification of the packaging of a traditional product and market leader for several decades is being studied because of complaints regarding the domestic conservation of the product. Communication received by Customer Service has also given rise to the return, in one region of the country, of the original formula of a product, whose alteration had produced complaints.

CONCLUSION

In all of the companies studied, the intention when creating Customer Service was for it to have a strategic role, contributing to improvement and growth in the organization. However, Customer Service at companies A and C appear to be encountering more difficulties than the others in fulfilling their mission: they rarely participate in meetings with other sectors; they have difficulties in obtaining responses and collaboration from staff in other areas; they are not consulted in decision-making, not even when these concern their activities.

The data collected illustrates that the position occupied by Customer Service in the company hierarchy is not enough to explain these differences. Customer Service at company D, whose actions have had a significant impact in terms of interaction with other sectors and the introduction of changes and innovation is separated from top-level management by two levels of hierarchy. In contrast, company C, whose activity is considerably limited, is separated from the President by just one level.

As regards the technology employed, with the exception of company C, all the companies have similar tools. Without doubt, the antiquated and precarious system adopted by company C contributes significantly to the sector's isolation. However, what appear to have the greatest contribution to the strategic nature of Customer Service activities are the efforts employed to integrate the sector into the rest of the company. In this sense, the use of the Intranet seems to have a relevant role. On one hand, it is a sign of the importance given to the mission and activities of the sector by top-level management. On the other, it transmits the idea that customer communication should be seen as opportunities to be made use of by the company as a whole and not as threats to be dealt with in secrecy.

In order to replace this view effectively, and permeate the organization completely, these tools need to be made part of a wide awareness project, capable of reducing the habitual resistance encountered by Customer Service and facilitating its relations with the rest of the company. Everything indicates that the internal bulletin at company B and the Integration Program at company D have played a crucial role in this sense. In promoting the integration of Customer Service into the company, they have ensured that information received and distributed by the sector is seen as relevant by other members of the organization, thus, effectively, contributing to its growth.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
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21

ERP SYSTEMS AND ORGANIZATIONAL CULTURE

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A DEMANDING TECHNOLOGY

A recent case description reports about a major ERP implementation at Nestlé, a multinational Switzerland-based consumer goods corporation (CIO.com, a website for Chief Information Offers related to *CIO Magazine*). The implementation involves an initial $200 million contract with SAP and an additional $80 million for consulting and maintenance. With this investment Nestlé wants to centralize a conglomerate that owns 200 operating companies and subsidiaries in 80 countries. The report cites a business analyst who downgraded her recommendation on Nestlé stock. She is skeptical about a project of this magnitude, because: "It touches the corporate culture, which is decentralized, and tries to centralize it… That's risky. It's always a risk when you touch the corporate culture." The responsible CIO of Nestlé also is very aware of the risky nature of ERP, and warns: "If they go in with an attitude that there's not going to be resistance and pain, they're going to be disappointed." This CIO has learned the hard way that "no major software implementation is really about the software. It's about change management." She stresses in particular that "when you move to SAP, you are changing the way people work… You are challenging their principles, their beliefs and the way they have done things for many, many years."

This account of ERP stands in sharp contrast with the rhetoric that guided the introduction and distribution phases in the development of Enterprise Systems. In the mid 1990s, when many organizations jumped on the ERP bandwagon, ERP was advocated and welcomed as a cure-all for many major organizational problems (Davenport, 1998). ERP promised significant increases in management control, competitive advantage, reductions in the costs of business operations and flexibility in production and distribution processes. While these advantages are still the primary objectives of ERP, these advantages are nowadays no longer naively presented as relatively simple and self-evident outcomes of a technological fix. Instead, ERP itself is presented as problematic, laying heavy burdens on organizations. This redefinition of ERP is informed by alarming stories about chronically exceeded budgets and deadlines and serious disruptions of business processes because of ERP. In short, the image of ERP seems to have changed from a highly promising into a highly *demanding technology.*

The Nestlé story not only draws attention towards transformations in the signification of ERP, it also points towards organizational culture as the primary factor responsible for the demanding character of this technology. Whether or not this claim is entirely accurate – it could well be that "culture" in some instances is used as a scapegoat, distracting from an underestimation of the complexity of ERP, from technical failures, financial miscalculations or bad management and power struggles – this claim strengthens our interest in the cultural conditions and consequences of ERP-systems.

In this article we develop a cultural perspective on ERP and organizations. We want to clarify what can or should be taken into account in a cultural study of ERP. We are specifically interested in the interaction between new technologies and organizations (Ciborra and Lanzara, 1990; Orlikowski, 2000). First, three different but mutually related perspectives on ERP will be highlighted. This is relevant for defining ERP. Second, the standardization of ERP is identified as a key process in the relationship between organizational culture and the dynamics of ERP. From a cultural perspective it is important to study the process of standardization from the perspective of the life worlds of the various actors involved in the development and implementation of ERP. In particular the role of intermediary ICT-businesses in constructing ERP seems crucial.

COMPLEX ORGANIZATIONS AND ERP

We start from the observation that ERP-systems are not easy to define, certainly not if we want to take the actors point of view seriously. ERP-systems are complex and dispersed within and between organizations. In a sense these systems are elusive; they are in constant flux and to be found everywhere (a little bit) and nowhere (entirely). Those involved in the (re)production of ERP will, dependent on their position in the organization, have quite different views of and experiences with ERP. Individual or group definitions of ERP will vary according to their 'awareness context' (Glaser and Strauss, 1964). In order to recognize these subjective standpoints towards ERP an a priory definition of ERP is not very useful. Instead, we highlight three perspectives from which ERP systems can be experienced, defined and analyzed. These perspectives, which indeed apply to any technology and which in a way also represent historical phases in the development and study of technology (Stemerding, 1995; Silverstone and Haddon, 1996), will in this article be specified as the "constitution" of ERP, ERP as a "condition" of organizations, and the (unintended) "consequences" of ERP.

The constitution of ERP

First, the constitution of ERP. This perspective refers to the material, time-spatial, appearance of ERP. It concerns the artefacts and persons ERP-systems are made of, including scanners, PCs, cables, mainframes, software packages (with brand names like SAP, Peoplesoft, Baan, Oracle or JD Edwards), interfaces, reports and ERP consultants, programmers and operators. In the field of technology studies Pinch and Bijker's (1987) discussion of the bicycle may serve as a typical example of the social construction of technological artefacts. He showed that and how the evolution of this vehicle could be understood by studying the interests and perceptions of the various actors involved in its use and development.

The ensemble of ERP-components can probably never be grasped as a unity, but each individual that has to do with ERP will in one way or another interact with at least some parts of it. The constituent parts themselves as a rule already represent complex technologies of which in everyday working routines and specific incidents only certain aspects will be considered relevant for ERP. For instance, a PC used for the input of ERP data can perhaps also be used for e-mail and surfing on the Internet.

Just like the Internet, the virtual character of ERP as a whole may obscure its physical foundations. Similar to the argument Downey (2001) makes for the Internet, ERP-workers can only be revealed if we consider technology, labor and space (and time) simultaneously. Therefore a cultural study of ERP should devote serious attention to the material and geographical aspects of these systems. Moreover, anthropological conceptions of organizational culture usually not only refer to values and rules but also to material artefacts (Schein, 1992), which increasingly consist of ICT equipment. And artefacts are endowed with symbolic meaning. This makes the attribution of symbolic meanings crucial for conceptualizing ERP in terms of its constitution.

In studying the interactions between man and machine, the question of the redefinition of the workplace and the required knowledge, tasks and skills is particularly relevant. ERP for instance seems to imply a switch from a functional to a process orientation, due to the fact that software modules cut across traditional departmental lines (Gunson and de Blasis, 2002). But direct and unambiguous relations between specific ICT systems and working positions are difficult to discern. Krueger (1993) for instance reported in a well-known article that people working with computers had significant higher levels of education and significant higher salaries than people working without them. This seems to confirm popular beliefs and policies about the relationship between computer skills and job opportunities. However, as Borghans and Ter Weel (2000) argue, different interpretations are possible and the causality can even be the other way around. It can be that people with higher wages have a greater chance of obtaining computers than people with lower wages. Also, the link between education and computer use doesn't have to refer to computer skills but can just as well refer to jobs that require complex analytical and social skills that are complementary to the tasks a computer can perform. It remains as yet an open question to which extent, and under which conditions, ERP generates more complex working relations and challenging work or generates de-socialized and de-skilled work and more standardized working routines. In this respect a study in the paper industry by Vallas and Beck (1996) might be revealing. They argue that the introduction of a computerized distribution control system, designed to enhance flexibility, led in their case to the devaluation of traditional craft knowledge and constraints on the workplace of manual workers.

For that matter, a concern for the redefinition of the workplace also involves higher management. Martinsons and Chong (1999), for instance, point at changes in the ICT management paradigm, from primarily technology driven towards more user-driven approaches. A change in this direction could very well be reinforced by ERP, since the management of primary business processes is to an increasing extent mediated by the ERP-system. In that case ICT will be prominently represented and discussed in the boardroom, because management objectives have to be translated into system requirements.

In general, the implications of ERP for working positions will probably vary according to the circumstances and the standpoints of those involved. Liker e.o. (1999) conclude from their extensive survey of the literature on the impact of technology on work, that this impact varies with different theoretical perspectives and is "contingent on a broad set of factors, including the reasons for its introduction, management philosophy, the labor management contract, the degree of a shared agreement about technology and work organization, and the process of technology development and implementation" (Liker e.o., 1999, 577).

ERP as a condition of organizations

Second, ERP as a condition of organizations. This perspective refers to the functional integration of (sub)systems by ERP. It concerns the infrastructure that results from the connections, laid by ERP, between various organizational networks, in particular functional divisions within organizations (like finance, marketing, procurement, warehousing, human and material resources planning) and between organizations (like various suppliers and customers). Indeed, within the history of ICT systems ERP is generally considered and defined on the basis of its capacity to integrate formerly segregated ICT systems. In this respect ERP represents a new phase in the informatization of organizations. In the field of technology studies Hughes (1987) study of electrical system may serve as a major example of modern technologies as infrastructures. He stressed that technological systems not simply comprise physical artefacts but involve heterogeneous interactions between organizations, sciences, markets and state regulations.

ERP may contribute to the development of 'network enterprises', defined by Castells (1996, 187) as 'that specific form of enterprise whose system of means is constituted by the intersections of segments of autonomous systems of goals'. This type of organization is rather flexible because it can both reallocate its means of production and change its goals. Network organizations can reconfigure themselves in reaction to changes in their environments. According to Castells network organizations are facilitated but not determined by ICT. Other factors are equally important, notably economic forces driving towards greater flexibility of management and cultural forces stressing individual freedom of choice.

Literature on the interaction between ERP and organizations indicates that ERP systems are developed and changed by several independent actors without any explicit coordination (Ciborra e.o., 2000). As a consequence these ICT-systems appear as large, open-ended infrastructures. Ideally, these infrastructures make it possible to flexibly manage entire business cycles and global business relations in real time. In this way ERP-systems produce time-spatial relations. In order to speed up the turnover time of capital, they are directed at 'time-space compression' (Harvey, 1989). For instance, formerly remote units appear nearby and formerly time-consuming procedures for gathering and comparing information from different locations and operations can be realized instantaneously. However, the spatial and temporal integration as promised by ERP does not automatically result from the implementation of these systems. The extent and specific forms of time-spatial reorganizations can vary considerably according to the contexts of application.

Castells' concept of the network enterprise is closely related to that of the 'virtual corporation' (Davidow and Malone, 1993). Information technologies that link employees, divisions and companies, and provide information anytime and anyplace, enable and reinforce network structures. For those involved, organizations mediated by ERP assume a highly virtual character, because although the situations represented by the bits and bites within the central database are real they are not actually present (Shields, 2002). The stored information presents an image of the organization and adds to the transparency of organizations. The virtual images of organizations, extracted from organizations and represented by ERP, become relatively autonomous from the physical properties of organizations.

This virtualization also enhances the capacity of panoptic control and disciplinary power (Foucault, 1977), an architecture of power closely associated with ICT systems (Zuboff, 1988; Poster, 1990). Management can use the stored information to monitor and correct the performance of individuals and divisions. At the same time individuals can be empowered by the system and carry out their tasks with more responsibility based on their own insights, preferences and information from the system. However, Sia *et al* (2002) studied the balance between control and empowerment in a hospital setting and concluded that ERP in this context tended towards the enhancement of managerial control.

In studying the disciplinary power, exerted through or on behalf of panoptic ICT systems, the standard protocols and implicit norms of ERP infrastructures are perhaps of greater relevance than the issue of the potential managerial surveillance of personnel. The connections within and between organizations necessitate close cooperation and the adjustment of successive business processes. This may effect the identity formation of individuals and groups within organizations, since identities refer to internal and external images of the 'self' (Jenkins, 1996). Precisely the internal and external (hierarchical as well as functional) boundaries can be effected by ERP. The standard procedures of ERP contain a "script" for users, informing them about what actions should be undertaken, when, where and how (Akrich, 1992). This implies also instructions from the system on the workplace about how to organize activities vis-à-vis co-workers, management and other elements in the business cycle. These normative scripts are crucial for conceptualizing ERP in terms of infrastructures. It may operate in a similar self-evident way as roads from the traffic system do, guiding drivers towards their destinations.

The standard solutions, build into ERP by the major providers, are based on so called "best practices", i.e. the ideal script for the most effective and efficient performance of certain business functions. But to what extent the standard solutions actually fit organizational requirements, or should be tailored to specific work environments, seems notoriously problematic (Davenport, 1998; Batenburg e.o., 2002). In this respect Soh e.o. (2002) offer an interesting typology of "misalignments in ERP Implementation" based on four structural properties of ERP. They argue that the quest for the integration of business units, a process orientation, greater flexibility, and generalized solutions, creates tensions with opposite organizational forces demanding differentiation, a functional orientation, stability and domain specific - for instance nation or region specific - solutions.

In addition the whole idea of objective "best practices" seems problematic. Even on the level of total software packages this claim doesn't seem to hold. For instance, SAP is generally considered strong on financial management, Baan on logistics and Peoplesoft on human resources management. Moreover, these software packages are implemented in organizational contexts, like hospitals and universities, which seem to deviate considerably from the contexts in which these packages have originally been developed. The interesting question here, of course, is to which extent this points towards a great flexibility of ERP software or to a homogenization of business models across a variety of organizational contexts.

The (unintended) consequences of ERP

Third, the consequences of ERP for organizational culture and the wider environment. This perspective refers to the actual effects of ERP, and concerns the intended as well as unintended consequences. Here we have to take into account that technologies do not determine effects in a simple linear fashion. "Effects" are in many cases controversial and a product of power relations. Indeed, power balances seem crucial for conceptualizing ERP in terms of its consequences. It is therefore important to study the effects of technologies in terms of the mutual change of and interactions between technologies and their environments. In the field of technology studies Schwartz

Cowan's (1983) study of modern household equipment, may serve as a major example of unexpected consequences of technologies. She showed that instead of making domestic labor easier, technologies like the washing machine could also aggravate domestic labor for housewives.

Effects concerning the scaling-up and globalization of, and managerial control over, business processes seem particularly relevant for ERP. Firms operating in extended networks and global markets in some way have to control their global operations and manage networks in a coordinated manner.

ERP systems may contribute to globalization in roughly two ways. Firstly, as a software product they may lead to the proliferation of standardized business solutions based on the alleged "best practices" (usually based on western capitalistic enterprises), more or less similar to the process of *McDonaldization* as described by George Ritzer (1993). This raises questions about the displacement and rearrangement of former localized business practices, identities and labor markets. In addition, the standardization can make it relatively easy to move business units towards the most profitable regions, for instance those with relatively high levels of education or relatively low wages. This may influence local business networks and communities. But to what extent ERP actually leads to the transformation of historically grown business practices, or elicits local responses, will also depend on the power relations involved. In this respect scholars have argued that globalization in many cases can better be understood in terms of "glocalization" (Robertson, 1995). This concept refers to the blending of global standards and local situations, like in the Japanese business strategy of *dochakuka*, a global outlook adapted to local conditions. The concept of glocalization challenges the widespread view that globalization and localization are separate and opposing ways of thinking.

Secondly, as the backbone of business processes ERP systems may contribute to the coordination of businesses on a transnational level. After all, the main managerial objective behind ERP is to enhance control over processes within separate user organizations. However, in the context of globalization it remains to be seen to what extent managerial control over the implementation of ERP and over global business processes can actually be realized. In particular Ulrich Beck (1992) has argued that the relative autonomy of modern science and technology produces all kinds of uncontrollable risks and side effects. According to Beck the awareness of these risks strengthens the *Risk Society* (1992), which is marked by a reflexive attitude towards unintended consequences of business strategies and market mechanisms. The acknowledgment of risks may in its turn change the conditions of their existence (Van Loon, 2002: 21).

Hanseth e.o. (2001) have argued that the dynamics of the Risk Society apply to ERP systems. And increasing risk means decreasing control. The risks increase as ERP effects everybody and everything in and around a corporation. In addition, modern corporations also get more integrated with their environment (customers, suppliers, partners, stock markets), implying that such companies get more effected by events taking place in other companies. Hanseth e.o. even argue that in their study of a global Norwegian oil company the introduction of ERP has led to outcomes opposite to the intended increase of managerial control. They suggest that ERP in the context of a global enterprise can be characterized as a runaway device, which behaves in unforeseen erratic ways. Although they can be counter productive, these erratic effects are not necessarily negative. For instance, the re-engineering of business processes within the oil company studied by Hanseth e.o. appeared to be "self-reinforcing" - integration generating more integration - as a side effect of the ERP implementation. In this case ERP had similar unexpected consequences for other IT systems, like the hardware infrastructure and the use of Lotus Notes software. Especially the introduction of Lotus Notes significantly improved the necessary collaboration throughout the company, which also effected the corporate culture.

ERP AND ORGANIZATIONAL CULTURE

In the previous section we have concluded that whether we study the constitution of ERP, or consider ERP as a condition of organizations or direct our attention towards the consequences of ERP, in each case the outcome of our analysis will be dependent upon the perception of the actors involved and the organizational contexts. These complex relationships between ERP and organizations raise the question of how to study and manage cultural aspects of ERP systems. Analyzing ERP as an outcome of human actions and interactions can be done by connecting ERP to a body of literature that is known as 'social shaping of technology' (SST) (Williams and Edge, 1996; MacKenzie and Wajcman, 1999). In contrast with approaches that consider technological development in a deterministic way as an autonomous process and as taken for granted, this body of literature examines not only technical factors, but socio and economic factors as well. Though using a wide range of theoretical models and frameworks, SST literature has in common that it studies the character and influence of shaping forces.

Central to SST literature is that there are choices made by individual actors or groups, which influence the character of artefacts and direction of the technological development (the so-called innovation trajectories). This implies that the understanding of choices and social influences is crucial. When it comes to the implementation of ERP in an organization, this means that the technology and the organization (i.e. organization members) cannot be treated as independent and separate entities. According to SST kind of literature, it is the social setting of the organization that shapes technology and vice versa (Ciborra and Lanzara, 1990). Technologies do not come to us like 'manna from heaven', but are social and heterogeneous phenomena embedded in social structures of organizations. Of particular importance are the interactions of people acting within these formal structures and in how they construct their own vision of reality. An analysis of the organizational context of actors should therefore be part of the analysis.

In our view, SST encompasses all the three perspectives on ERP as outlined above. These perspectives should not be considered as mutually exclusive but as alternative cross-sections of the same technology-organization constellation. Whereas questions related to the constitution of ERP tend to highlight the *meanings* attributed to ERP artifacts, and questions related to ERP as an organizational condition tend to focus upon the *normative prescriptions* embedded in the operation of ERP, the questions related to the consequences of ERP highlight the *power relations* regarding ERP. The intellectual challenge here is to analyse how these three perspectives interact and can be combined in practice.

Organizational culture

It is at this point that we want to bring in the concept of organizational culture. In the literature concerning ERP 'culture' is – if it is referred to at all - often implicitly or loosely defined. But a cultural study of ERP should make culture more explicit. In general we propose a classical anthropological understanding of culture as a more or less shared system of symbols and meaning (Geertz, 1973). However, in the context of modern societies and formal organizations two complicating processes should be taken into account.

First, the distinction between a life world and a systems approach of organizational culture (Tennekes, 1995). As can be derived from Habermas (1989) formal definitions, a systems approach brings to the fore the instrumental actions of and within organizations, and stresses the coordination between people and divisions on the basis of hierarchical power relations and anonymous market mechanisms. Many studies of ERP dealing with the effectiveness and efficiency of ERP implicitly or explicitly approach ERP from such a systems point of view. In contrast with this, a life world approach focuses upon communicative actions and stresses the coordination between people and divisions on the basis of normative agreement and feelings of mutual understanding. A life world approach can offer a detailed understanding of the motives and identities of the actors involved, in particular through the use of ethnographic methods and discourse and narrative analysis (Czarniawska, 1998). Alvarez and Urla (2002), for instance, applied a narrative analysis in a case study of a system requirements analysis regarding an ERP implementation. They remark that the narratives concerning the requirements for ERP also learn something about the culture of organizations. This is not surprising, because in stressing the importance of a life-world approach the systemic aspects of organizations should not be neglected. They should rather be considered as two sides of the same organizational coin. It is the mutual relationship that has to be questioned. Technologies are part and parcel of organizational culture and this culture is reproduced in everyday working routines.

It has already been argued that with the introduction of ERP the instrumental actions within and between organizations increasingly tend to be coordinated by ERP. Therefore organizational cultures assume the character of 'technological cultures', i.e. cultures which are primarily mediated by technology. This can have serious consequences for organizational "sensemaking" (Weick, 1995). As defined by Weick, sensemaking is both an individual and a social activity and does not only refer to the interpretation but also to the construction of meaning. Weick furthermore stresses the retrospective character of sensemaking. This makes sensemaking particularly relevant in situations where people are confronted with rapid changes, complex problems and unexpected outcomes of innovations. These circumstances force people literally to make sense of what is going on.

Second, the fragmentation of organizational culture. Organizational culture has often been described as a pattern of shared assumptions produced and manipulated by top management (Schein, 1992). However, the description of organizational culture as a set of shared assumptions is rather oversimplified and often misleading. Empirical research provides us with a far more complex picture and shows that tensions can grow and remain between the individuals' interests and organization aims (Kunda, 1992). Therefore, organizational cultures should be studied in line with Martin's theoretical observations (Martin, 2002). She argues that because of cognitive and normative diversity within an organization, the attribution of meaning (which is, as we have argued, an central part of the cultural process) is complicated and leads to integration as well as fragmentation, unity as well as diversity. It is the actor's reality that forms the basis for further action – people produce and reproduce organizations by means of actions and interactions on a daily basis (the so-called routines).

From a structurationist framework it has been stressed, in particular by Orlikowski (2000), that individual actors are always situated actors. In using technologies actors reproduce at the same time important normative and power relations within and between organizations. Thus linkages can be specified between on the one hand the meanings attributed to technologies and on the other hand the normative prescriptions and power relations of organizations. In this way it is possible to analyze culture in terms of 'shared' meaningful work practices, while at the same time recognizing the existence of multiple working cultures dealing with ERP. More specifically, it seems important to emphasize the mutual development of organizational (sub)cultures and the technical (ERP) structure upon which they rely (Kawalek and Wood-Harper, 2002).

The Standardization of ERP

The rise of ERP in organizations reflects a new phase in the informatization of organizations, integrating separate processes, like accounting, production planning, marketing and human resource management. The intended integration of complex organizations makes ERP a very interesting case for studying organizational culture and ICT, because these ERP-systems are dealing with the tuning of standardized solutions of specific routines within and between organizations (Holland and Light, 2001). In this sense, the standardization of ERP-systems is part and parcel of modernization processes, which are marked by processes of specialization and integration (Giddens, 1990; Beck, 1992).

The standardization of ERP is in our view reinforced by two basic processes: 1) ERP systems are generally implemented by intermediary business consultants mediating between the development of ERP-standard software packages and specific business domains of application (this is the 'vertical' integration of ERP); 2) ERP systems integrate complex networks of production divisions, suppliers and customers (this is the 'horizontal' integration of ERP). In order to study and manage the interaction between specialization and integration it seems of great importance to focus upon those organizations and working practices that explicitly deal with the 'vertical' and 'horizontal' integration of ERP-packages (see figure 1). Whereas the vertical integration refers to the standardization *of* ERP packages, the horizontal integration refers to the standardization of business processes *by* ERP. These forms of standardization are interdependent and should be studied in mutual interaction.

The vertical integration of ERP-packages represents the 'reproduction chain' of this type of Enterprise Systems, whereas the horizontal integration represents the 'value chain' of the production processes that are 'informatized' by ERP. Characteristic of the specialization of the services regarding ERP-systems, is that the development and implementation of these software-systems are relatively independent of each other. Because of this, specialized professions and organizations have originated which are dealing with the tuning of standardized solutions on specific organizations (Besson and Rowe, 2001). As a consequence, it may happen that the knowledge embedded in the ERP-software is in conflict with existing knowledge in the organization (Van Stijn and Wensley, 2001).

An interesting approach to intermediary structures has been developed by Michel Callon. Actors within the network are entities 'that do things' (Callon, e.o., 1992). Although the distinction between human and non-human actors is less interesting to Callon than the distribution chain itself, we would like to focus on intermediary firms. Intermediary firms provide the missing link between the producers and users of ERP. Moreover, due to their specific role, they define (partial) the network itself. Actors within an intermediary IT corporation 'translate' ERP packages into the production languages of the contexts of implementation, and therefore also change the ERP software. Following Callon we define an 'intermediary' as anything that passes in between actors (in our case the producers, consultants and users) just to make transactions possible. Intermediaries are thus to be seen as the language of the techno-economic network - it can be a text, a protocol, a patent, a service, or money. Considering this definition the way the actors interact in the techno-economic (ERP) network, lies at the heart of our analysis.

To illustrate this point, we can refer to a striking example of the intermediary role of ERP in an empirical research project we recently started. One case study concerns the experiences with ERP of a relatively small (600 employees) factory in the automotive sector. At a certain moment in time within this factory the materials requirement planning (MRP) got out of control, and the production process almost came to a halt. There was a serious misalignment between on the one hand the actual presence of materials at the production lines and in the warehouses, and on the other hand the virtual representation of these materials within the ERP system. Although this misalignment was rather obvious, most of those responsible at the production lines and in the warehouses continued taking the information given by the ERP system seriously and continued acting upon this information, more or less irrespective of the consequences their actions had for the (dis)continuation of the production process. This seemingly 'irrational' behavior can partly be explained by the 'fallacy of centrality' as discussed by Weick (1995: 3): the more advanced a technology is thought to be, the more likely are people to believe the information that comes out of it. In this way the perceptions of information technology can seriously influence the sensemaking of what is going on in organizations.

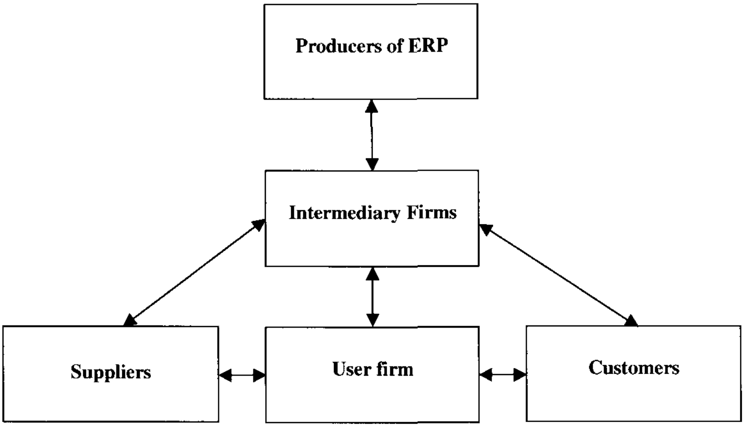

Figure 1. ERP in the organizational context

CONCLUSION

We started this paper with the observation that ERP has become a highly demanding technology. Managers as well as scientist in many cases attribute the problems associated with the development and implementation of ERP to aspects of organizational culture. However, in general – with some interesting exceptions cited in this article - culture has not yet been a topic of explicit concern in studies of ERP. Therefore we have given some guidelines for developing a cultural perspective on ERP.

First, in defining ERP from the actors point of view three different but mutually related perspectives should be taken into account. These perspectives include the constitution of ERP (stressing processes of signification and the redefinition of work), ERP as a condition of organizations (stressing the virtualization of organizations and normative prescriptions of ERP) and the intended as well as unintended consequences of ERP (stressing the globalization of organizations and power relations). In the interaction between these three dimensions of ERP we may find the cultural forces shaping this technology and how this technology in its turn influences organizational cultures. Since many studies of ERP highlight the gaps that often seem to be experienced between the expectations and evaluations of ERP projects, special attention should be given to the retrospective character of cultural processes, as in the concept of sensemaking (Weick, 1995).

Second, in studying culture the actor's point of view is paramount, since culture refers to processes of meaning construction and sensemaking. The actor's point of view can be pursued by adopting a life-world approach. However, life-worlds should not be approached without taking the instrumental systems characteristics of ERP into consideration. It is important to specify how IT-systems and life-worlds are connected, since cultural relations are reproduced together with the development and use of ERP-systems. System and life-world will have to be perceived as two sides of the same organizational coin. In this respect we have stressed the importance of 'intermediary' structures and organizations. These structures, and the organizations specifically dealing with these structures, provide linkages between the producers and users of ERP. Accentuating intermediary structures, and intermediary roles of ERP, can also overcome the often arbitrary distinction between human and non-human 'actors' (Callon e.o., 1992).

Third, the standardization of ERP systems is of interest in order to identify the relevant actors regarding ERP. In the standardization of ERP-systems a distinction should be made between on the one hand the standardization *of* ERP, i.e. the vertical integration within the '(re)production chain' of ERP packages, and on the other hand the 'value chain' standardized *by* ERP, i.e. the horizontal integration of business units and suppliers and customers. In managing these processes of standardization, intermediary ICT companies, and other working practices that specifically deal with the connections between the various sub-systems of the ERP-network, occupy key positions in the social construction of ERP. Together they make up an organizational context for ERP, which has become a relatively autonomous force within and between organizations. This technological environment exerts considerable influence upon but does not determine organizational culture. It shapes a technological culture with which management and researchers seriously have to reckon with.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
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22

REAL OPTIONS IN TECHNOLOGY INCUBATORS

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INTRODUCTION

This paper extends real option theory from its financial industry origins and initial R&D applications to the growing practice of high-technology incubation. We define an incubator narrowly to be both a service firm and risk investor that supports early-stage technology start-up companies through strategic business guidance and direct equity investment. Incubators are constantly managing high uncertainties regarding future technologies, potential markets, and team development. Returns on investments in specific start-ups may be realized through equity shares in portfolio start-ups, and to some extent through coaching and service fees.

Incubators became a popular instrument of for-profit start-up facilitation during the heyday of the Internet bubble in the late 1990s. After the New Economy collapse in April 2000, many high-tech incubators had to close down after operational budgets were depleted and investors withdrew their funding. Not-for-profit incubators have survived this shake-out largely unscathed, as have those for-profit incubators with a clear customer value proposition and efficient risk management strategy.

What is at the core of this proposition that separates the successful from the unsuccessful incubators? We argue that successful for-profit incubators offer more than just convenient facilities, management advice and funding. Rather, they are in the business of reducing uncertainty and shortening 'time-to-knowledge'—the accumulation of key information on a company's likelihood of success or failure. As an early stage investor, the successful incubator secures a premium on reducing as much risk across as little time-period before "passing on" the start-up to the next professional round of venture investment. Thus effective risk management across a subsection of the R&D innovation pipeline is at the core of the incubator's business model. The similarities between traditional R&D and incubation are numerous, particularly when including technology-based new business development, although some essential differences remain. Nevertheless, there is a substantial and still underexploited potential for mutual learning between independent incubators and industrial R&D.

With this paper we aim to draw an analytical and practical bridge between traditional R&D risk management and the emerging high-technology incubation sector in the context of real option theory. More specifically, we intend to make the following contributions:

- Reviewing the potential of real options as used in R&D management for use in incubating start-up ventures;
- Distinction of macro and micro perspectives of risk in incubation;
- A real option reasoning based assessment for incubating start-ups.

The paper is organized as follows. In Section 2 we review some important developments with respect to project evaluation and decision making in R&D operations and our assumptions leading to this paper. In Section 3 we summarize the real option method and illustrate its applicability beyond the financial industry to the R&D sector. Section 4 clarifies the role of incubators as uncertainty reducers and risk brokers. The core of this paper, Section 5 introduces a real option theory based assessment tool for incubation. Section 6 concludes with a discussion and reflection on the practical limitations of the model.

CONCEPTUAL FRAMEWORK

Literature on Decision Making in R&D

Our analysis provides a link between three principal fields of study: R&D management, real option theory, and incubation. The key tasks of an R&D manager are to make sound investment decisions, develop effective technical strategies, and orchestrate the appropriate mix of human and financial resources. Generally, this process begins with the initial R&D proposal. If a project proposal is approved, funds are allocated from the overall R&D budget, manpower is assigned over a certain period of time to develop the technology further, and resources are reserved to execute the project as smoothly as possible. In other words, money is spent on a project with an uncertain outcome. If the project proposal is rejected, the company may have forfeited the opportunity to develop a potentially profitable business and perhaps the establishment of a new core competence of the firm. Academics would speak of the incurrence of opportunity costs, or forgone profits due to a deliberate decision. While the R&D manager is not the only decision maker to influence the course of this project, he or she is arguably the best informed and most directly affected by the consequences.

Over the past decades, the expectations placed on the R&D managers' strategic decision making ability have increased. Traditionally R&D managers had to consider the technical feasibility of a project and the availability of sufficient funds from the R&D budget based on the directives of senior management. This position has moved up the corporate chain of command, and the R&D manager has now more decision-making responsibility. Indeed, with the shift from technology push to market pull, customer needs and market potential have become important criteria to evaluate R&D initiatives. This is even more apparent with the heightened technical competitiveness in many industries as well as the critical role played by intellectual property rights, which are secured as a result of coordinated R&D efforts. Today both literature and practice suggest that individual R&D projects are not considered as isolated exercises within a corporation, and investment decisions are increasingly aligned with business and technology strategies in mind (see e.g. Roussel et al., 1991). Increasingly R&D managers are also responsible for the financial viability of the projects they approve and participate in the ensuing competitive strategy of the produce or service roll-out into the marketplace.

In order to fulfil the mounting expectations, R&D managers have been given increasingly sophisticated tools to make these decisions. Instruments such as Quality

Function Deployment (QFD) and Failure Mode and Effect Analysis (FMEA) improve R&D management both in terms of effectiveness and efficiency. An underlying assumption to most instruments, however, is still the notion of R&D as a linear or sequential process. Takeuchi and Nonaka (1986) proposed a "rugby" approach to R&D, integrating various contributors to the entire R&D effort according to the principles of simultaneous engineering. Cooper (1990) described the phase review process for new product development, which consists of a predetermined set of stages separated by checkpoints, or gates. This "stage-gate" approach, as it is often called, does not consider option characteristics within R&D (see also Lint and Pennings, 2001).

Standard discounted cash flow methods, such as net present value calculations (NPV), dominate the project evaluation process (Newton et al, 1996). More recently, real options have been considered for R&D decision-making (as documented in the special 2001 issue in R&D Management). Real option methods are superior to NPV calculations as they consider the value of flexibility in light of uncertainty (e.g., Copeland, 2001). Real options are, however, still far from becoming a standard means of project investment decision-making in R&D. The number of companies deploying real options for R&D investment decisions is small, and much of the relevant literature is concerned establishing real options as an alternative to the NPV method.

The incubation of technology-based start-up ventures has been likened to the management of R&D projects (see e.g., Ruping and Zedtwitz, 2003). In both cases, managers face high technological and market uncertainties, difficulties of team formation and growth, and resistance from established businesses and organizations. Incubation is still a fairly recent phenomenon, at least in its for-profit version, and several methods used in R&D management have been adopted and refined for use in incubators. Being relatively new to R&D management, real option has yet to make this transition.

Research Methodology

In order to assess the value of real options in incubation, we used a framework developed for comparing R&D management and incubation (see Ruping and Zedtwitz, 2003). This framework is based on a risk-optimizing pipeline of projects under incubation. It was developed based on the extensive personal experience of one of the authors with incubation, and explorative research of several dozen incubators located in the US, the UK, and continental Europe.

Between 2000 and 2002, we conducted 66 research interviews with managers from 50 incubators. Specifically, we asked them about start-up selection, pipeline management, decision making, resource allocation, risk management, and their incubation business model. We focused our selection of incubators operating in high-tech industries—e.g., IT, bioscience—and demonstrated productivity (at least one year of operation, at least one graduated start-up). We interviewed both for-profit and not-for-profit incubators, and incubators that were either self-sufficient or associated with universities, local municipalities, and industrial companies. Most of these incubators were located in the US, UK, France, Germany, Switzerland, and China.

In addition to the research interviews, we collected information provided by the incubators themselves, e.g., company brochures and websites, and information from third parties, e.g., industry reports and trade association listings. We talked to entrepreneurs being incubated (so-called incubatees) as well as some of the external service providers associated with incubators. We communicated our findings to the interviewed incubators and sought their feedback to eliminate possible differences in perception and interpretation. Although some of the information obtained in the interviews was confidential, we strived to adhere to Yin's (1994) principle of data triangulation to ensure a sound qualitative research methodology.

REAL OPTIONS IN R&D

An option is generally defined as the right, but not the obligation, to take a future course of action. This is most commonly employed in the financial sector where investment decisions are made in a highly volatile environment of uncertain risk. A stock option, for example, allows an investor to buy a stock at a certain set price (favorably if the share price of the stock is above the set price), but does not obligate the option owner to buy the stock (if at or below the set price). A real option, by comparison, deals with the right, but not the obligation, to buy an asset not traded as a security in the financial market. An example of a real option is the future capability to introduce a new product into a market. In short, a real option buys the right to take advantage of the up-side of an opportunity without being obligated to the down-side of an investment in an asset. The desire to undertake such an action is enhanced by improved information accumulated over the time of the pending option. Thus real options are more valuable in highly volatile and uncertain environments.

The similarity between a stock option and an R&D project has been recognized for some time, as both options give the investor the opportunity to capitalize on developing information over time in order to secure future earnings while limiting the potential loss. Real option methods recognize and exploit the value of flexibility that leads to a more accurate perception of the value of risky projects. Precisely because real options recognize that risks can be managed by making future decisions about projects as uncertainties become resolved, their use usually leads to higher values for the same projects compared with traditional evaluation schemes such as the net present value method.

The most widely used financial option model is the Black-Scholes model (Black and Scholes, 1973). The underlying assumptions of the Black-Scholes model may present R&D managers with difficult application problems. For instance, the Black-Scholes model assumes that the future value of the investment is distributed log-normally and cannot be negative. This may not be the case with the future value of cash flows received from implemented R&D projects (see e.g. Angelis, 2000). Trigeorgis (1993, 1999) discussed the problem of determining the value of the underlying asset of a real option (as required by Black-Scholes). Since R&D projects are typically not traded in the market, this is difficult if not impossible to establish. Finally, volatility is derived from the final stock price divided by the initial stock price ('price relative') and obtained from historical data, which again usually do not exist for R&D projects.

Some authors have employed a decisions analysis approach to overcome the limitations of the Black-Scholes model. Morris et al. (1991) described how projects with negative NVP have a positive value when the option to abandon the project is incorporated in the model. Their analysis combines the two uncertainties of revenues and costs into one probability of net benefits and using a normal distribution modeling the possible values. Angelis (2000) suggested overcoming the limitation of estimating the distribution of net cash flows by using two separate estimates for production and marketing costs, and anticipated revenues.

Neely and de Neufville (2001) differentiated risk into two categories: project risks and market risks. Project risks are risks unique to individual events and as such can be guarded against by diversifying investments over a portfolio of projects. Projects can be properly evaluated through an expected value decision analysis. Market risks are risks that cannot be avoided by project diversification. Real options analysis alone is properly equipped to treat a number of different market risks. They suggest a hybrid real options approach using the options method for market risks, and decision analysis for project risks.

Real options introduce the value of flexibility into R&D project analysis, and seemingly attach a numerical value to managerial intuition. There is a strong temptation to quantify these values and use it for managerial guidance. There are, however, some fundamental problems in relying exclusively on such analysis (see McGrath and MacMillan, 2000):

- Opportunities that can be quantified with any degree of confidence are not, by definition, uncertain, and hence conventional approaches may be used.
- There is no universal option value as the value of an investment is a function of the capabilities of the specific firm making the investment.

Although a precise calculation of option value may not be meaningful, applying real option reasoning to R&D decision making may still be very worthwhile particularly in situations where R&D management decisions are not driven by numbers and plans but rather by problems solving measures and changes in the competitive environment.

WHAT ARE INCUBATORS?

Competitive Scope and Strategic Objectives of Incubators

Incubators are in the business of facilitating entrepreneurs and early-stage start-up companies, and they sometimes compete (or cooperate) with consulting firms, real-estate agents, and other companies in search for the most interesting and valuable start-ups. Incubators differentiate themselves through their particular competitive scope, strategic objective, and service package. Following Porter (1986), we discern four different elements of competitive scope:

1. *Vertical scope*: Along with venture capitalists, business angels, consulting companies and institutional investors, incubators provide financial and managerial support to start-up companies. Incubators target early-stage start-ups, but they try to differentiate themselves from business angels in their institutionalization of coaching and other start-up services, and hence are less likely to concentrate on the first-time entrepreneur. At the downstream end, venture capitalists are often exit partners or customers of start-ups successfully graduating from incubators. In this respect, incubators serve as start-up clearing houses (i.e., risk-filters) for venture capitalists.
2. *Segment scope*: The source of start-ups can provide another competitive factor for incubators. For instance, university incubators typically give preference to faculty and student entrepreneurs from their host university. Corporate-internal incubators

prefer employees to external entrepreneurs: For example, BT's Brightstar incubator offers its service to BT employees only. Some independent incubators have relied on key people being responsible for generating ideas for new start-ups (e.g., IdeaLab), but this model is extremely dependent on the creative minds behind the incubator. Other incubators keep their doors open to a variety of sources.

3. *Geographical scope*: Geographical focus is a natural competitive factor for regional business incubators, since their mission is to support new business locally. Network access is a crucial element of successful incubation. Since networks are usually limited to certain regions, many incubators strive to establish a good local presence. The exceptions here are some internal corporate incubators—where the company network is more important than the regional network—and many virtual incubators, which base their business models on the variety of start-ups rather than a particular geographical focus.
4. *Industry focus*: Incubators may focus on a particular industry because of the professional preferences or competencies of incubator managers, or to create synergy among incubating entrepreneurs. Typical industries are information technology, Internet services, software and biotech. Even some university incubators concentrate on given technologies, but their focus is driven by the size of the infrastructure investment or the reputation of certain academic departments. The incubator at Boston University, for instance, focuses on photonics and opto-electronics, and has invested approximately US$100 million installing state-of-the-art research and experimentation infrastructure.

These four dimensions of competitive scope help to explain not only how incubators differ from other start-up facilitators, but also how they differentiate among themselves. Incubators also differ in their strategic objective for supporting start-ups: whether they are offering their services for profit or not for profit. This differentiation is more than just a superficial academic distinction. It fundamentally affects the design of the incubator's business model and the execution of the incubator's business plan. The opening spectrum of competitive focus and strategic objectives has led to the archetyping of incubator forms, offering different benefits to different clientele.

The most common archetypes of incubation are:

1. Regional business incubators
2. University incubators
3. Independent commercial incubators
4. Company-internal incubators
5. Virtual incubators

A discussion of these archetypes can be found in Zedtwitz (2003). The first two types are generally not-for-profit oriented, while the latter three forms have strong for-profit objectives. All types differ strongly in their choice of—or opportunity for—competitive focus.

Customer Value Proposition of Incubators

Entrepreneurs need business facilitation services such as funding, office space, IT infrastructure, coaching, etc. from incubators, consulting firms, real-estate companies, and other service providers. Based on our research, we identified the five services as central to incubation (Table 1). The actual service mix depends on the focus of the incubator as well as the needs and preferences of the entrepreneur (e.g., Nash-Hoff, 1998). An agreement between the entrepreneur and the incubator outlines this service mix, along with any service fees and the equity position the incubator will hold in the start-up.

Some incubators offer all five of these services: These are incubators in the strong sense of the term. Organizations that offer only four services are considered incubators in the weak sense of the term. Organizations that offer fewer than four of these services lack too many elements of incubation and do not satisfy our definition of an incubator. Rather, this is the domain of accelerators, technology-transfer offices or entrepreneur-in-residence programs of consulting and accounting firms.

An incubator must know the unique value proposition of the services it combines in one package. If it is unable to define the value of a particular service in the context of the package, it might be better to outsource the service. For instance, some incubators have decided to outsource stock option planning to more specialized accounting firms.

Most if not all of the listed services could be outsourced and merely aggregated by incubators. Why do they choose to integrate these services? Early-stage entrepreneurs have the following problems: They don't know whether their business idea is ultimately successful, and they don't have much time (or money) to find out. Time lags and conflicts of interest in decentralized organizations are well discussed in the literature. Entrepreneurs are willing to pay the higher price tag of centralized incubation in order to avoid opportunity costs of late product introduction, foregone revenues, or me-too innovation.

Table 1. Incubators offer a wide range of start-up facilitation services.

	What	How	Compete against who
Physical Infra-structure	Office space Desk, PC, telephone Amenities	Rent/lease Volume discount Shared use	Municipalities Science parks Real-estate landlords
Office Support	PC & Equip. Support Mail Services Secretary & Security	Hire staff Specialized local providers Reception services	Science parks Real-estate operators
Access to Money	Direct investment VCs & biz angels access Pseudo-salaries Grants	Incubation fund Milestone installment VC road/home-shows	Venture capitalists Business angels
Process Support	Professional services Coaching Mentoring	Preferred client agreem'ts Start-up training Business consulting	Law & accountancy firms Consultants
Net-working	Key employees Customers Collaborators	Rolodex Internal matchmaking Travel support	HR firms Networking organizations VCs and biz angels

Incubators are essentially offering to speed up business development and to quickly reduce uncertainty. Competitive focus not only signals the incubator's strengths and advantages, it also provides a clear definition of the most valued customer an incubator should accept in order to leverage its competencies most effectively. Graduation policies and increasing rent schemes force the entrepreneurs to focus on a proof of concept and moving the venture into the next stage of professional funding. Turnkey office infrastructure and flexible office layout (e.g., desks on wheels) help entrepreneurs to take up space quickly and efficiently. For an entrepreneur, beating the clock means beating competition. Successful incubators have understood this principle, and shelter entrepreneurs temporarily from outside tribulations so that they can focus on critical business building. There is no guarantee that the start-up is going to be successful, but at least the entrepreneur will find out fast. As a matter of evidence, Molnar et al. (1997) showed that survival rates of graduating start-ups were as high as 90% to 95% for for-profit incubators, compared with approximately 80% for not-for-profit incubators. Both figures are far better than the overall success rates of start-ups in comparable stages of less than 20%.

REAL OPTIONS IN INCUBATION

The incubator manager seeks to identify promising individual start-ups, assemble a portfolio of incubation clients that are complementary (or at a minimum that are not conflicting) and assist those companies in their development to the next level of investment. Parallel with this process is the continuous challenge to limit risk and maximize the "upside" opportunity of an investment. The incubator manager must be able to identify not only potential success but also failure: to filter out those start-ups that are not likely to succeed. The authors do not feel compelled to proscribe real option theory to incubators. Rather, we suggest that current best-practices at successful incubators implicitly incorporate real options, possibly without their managers recognizing the full implications. We propose that existing incubators can further benefit from a rigorous real option analysis of their activities, and that newly established incubators lacking experience or non-commercial incubators lacking a market mechanism for ensuing efficiency should adopt real options a guiding tool for venture project management.

Real Options at Different Stages

Real options are most valuable when uncertainty is the greatest, and the greatest uncertainty in the entrepreneurial life cycle is at the early stage of start-up development. Incubators generally operate at this highly uncertain "zero-stage" when business plans are unfinished, markets remain uncertain, technologies are under development, and companies are pre-funded and undercapitalized. Incubators also have the opportunity to secure substantial upside for those start-ups that succeed. A real option strategy of flexibly limiting long-term obligations to a failing start-up, while maximizing the upside of a promising start-up is an effective model for today's commercial incubators.

Different parties have varied reasons for participating in an incubator, whether as owner, investor, or strategic partner. For instance, later-stage investors such as mature corporations or VCs face the dilemma of securing high-quality deal flow while effectively filtering out risk. VCs may associate themselves with an incubator and refer those start-ups that are not sufficiently developed for its own investment criteria. The incubator accepts significant early-stage risk in order to secure future opportunities that will be "passed on" to later-stage investors—the later-stage VC in a follow-on investment or mature corporation in a strategic investment or acquisition—at a premium. At an early stage of start-up life, i.e., before significant resources are invested, the incubator retains the flexibility to terminate underperforming start-ups and to cease financial support. If the start-up is successful there is an opportunity to continue to participate in future funding and maintain or expand its equity position to take advantage of an eventual exit event.

For the mature venture capital fund, the incubator secures quality future investment opportunities by participating in follow-on funding as well as investment returns. An example is YankeeTec of Cambridge, MA, which has attracted among others Battery Ventures as a private equity investor. For the established corporation, this is an opportunity to outsource R&D in high-risk projects (in terms of business, politics, and strategy) and secure future corporate strategies in concert with portfolio companies. An example is the Panasonic Incubator in Cupertino CA, which is operated under its parent company Matsushita Electric in association with Panasonic Ventures, a corporate venture capital fund. For regional governments, incubators attract and support promising teams that will add to the local tax base as well as employment pool. An example is the Huston Technology Center, which supports start-ups emerging out of the greater Houston, Texas area. For the university, an incubator is a chance to bridge academic research with industry, providing financial opportunities for itself, market opportunities for its graduates, and a positive feedback loop for its academic labs. An example is Boston University's incubator in the Photonics Center, which supports university-sourced start-ups in the opto-electronic application field.

Real Options at the Macro-level in Incubation

The for-profit incubator has a simple charge: maximize returns for limited partner investors while developing a brand image among the community of early stage start-ups. Maximizing returns will attract the limited partners to continue supporting the incubator. Strong brand image among early stage entrepreneurs will attract potential client interest in the incubator resources. To satisfy these sometimes conflicting and sometimes complementary objectives, the incubator undertakes real option-like strategies on the macro-level and micro-level.

An incubator invests not just in one company but in a portfolio of companies. Thus, its management must consider macro-level investment strategies across a number of start-ups in addition to micro-level investments in an individual team. Macro-level strategic decision-making can benefit from a real option analysis. Put simply, equity investors seek to reap high returns by efficiently managing risks. To do so requires several elements at the macro portfolio level:

1. Quality deal flow;
2. Accurate information of existing and potential start-ups;
3. Effective analysis of that information;
4. Selective risk-averting actions to maximize (1) – (3) while securing a portfolio of investments across time.

It is this last element (4), which dictates the use of real option analysis. At the macro level, incubators undertake investments across a portfolio of different start-ups in order to maximize operational and investment returns while minimizing portfolio risk. In real option terms, the incubator management will undertake individual investments in order to secure future portfolio opportunities, such as seeding a new investment sector by taking an early investment in an uncertain company. Due to the uncertain future of start-ups, the incubator is buying the option for future investments (and returns) by supporting start-ups that would otherwise not reach the next stage.

The incubator can follow on with expanded investments, or cut its loss entirely in that sector if there is a change in outlook. A different example is to 'purchase' exposure to new start-up opportunities, for example through the sponsorship of a university business plan competition. Usually this sponsorship will provide the incubator with networking opportunities, preferred access to the business plan competitors, and an opportunity to engage in pre-investment due diligence with a number of potential clients. This general option is focused at the macro level: to generate a set of investment opportunities and to grow a portfolio of synergistic start-ups that result in a general risk matrix where individual start-up characteristics are complimentary to others. Along with the notion of purchasing real options of future incubation comes the realization of value added, and hence an increase in valuation of the start-up portfolio.

Real Options at the Micro-level in Incubation

Real option theory is even more compelling at the micro level of incubation. This is where the individual investment is considered alone as an investment opportunity. The incubator management will undertake a series of incremental steps of exposure. Each activity is undertaken at some real cash or opportunity cost in order to reach an option point at which the increased knowledge gained will assist in the analysis of the start-up's likelihood of success or failure. At that point the incubator can exercise its option or pass on the unattractive investment.

For instance, incTANK's business model is indicative of a general real option strategy. It involves several stages of information accumulation across time that requires internal costs or actual financial resources (option price) that will allow incTANK to pursue the next stage of involvement in the start-up (option right) that will eventually lead to an equity position and eventual investment exit (option value). Some of these stages do not include a formal contractual right, particularly at the early stage of networking and initial due diligence. At these stages the strict definition of a real option right must be relaxed to a real option opportunity to proceed or to terminate the interaction. At later stages when the start-up becomes a portfolio client, an incubation agreement or other investment contracts will secure real option rights that incTANK will have the opportunity to exercise as information is accumulated and risk is reduced. For example, a non-dilution clause in an investment vehicle gives the incubator the opportunity to secure its equity position by purchasing more shares along side new investors. At any time across this relationship, however, the incubator has the right to terminate its support of a particular start-up.

The incubator will invest the human resources (option cost) to amass the information necessary to asses the likelihood of success (or failure), after which the next step in the option history is faced: to extend non-financial support. At such a stage the start-up—now a portfolio company—has access to the incubation consulting resources, professional network of professional service providers, and "bandwidth" of an individual incubation manager. A further resource, offered parallel or subsequently, is access to infrastructure and office space.

REFLECTIONS AND CONCLUSIONS

During incubation, a technology leaves the world of R&D and enters one of venture capital, entrepreneurship, and business building. This new world is characterized by new risks and new costs. Is R&D management the right approach to guide technology into this world? Is conventional growth management the right approach? Real options seem to capture important elements from both approaches in a way meaningful to manage risks and uncertainties from technology, business, and—to some extent—people. The greatest danger is, perhaps, to believe in the computational power of real options in the context of incubation. The inherent complexity and unpredictability of incubation makes it difficult to use any numerical real option formulae, and hence the result is likely to be off. However, and this is a main argument in this paper, good incubator managers intuitively apply real option reasoning when making incubation decisions. We think that real options can be useful for incubation in the following way:

- Incubator managers should familiarize themselves with the theory of real options;
- Incubators should rely on real option reasoning to assess investment decisions in their specific context;
- Within bounds of experience, predictability and measurability, incubators should use simple but effective criteria and calculations to cautiously check incubation decisions.

  Thus incubators reduce risk, increase value, and expedite start-up development by marrying concepts used the financial world and, increasingly, in R&D.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

23

CRM, BEFORE TECHNOLOGY, GO BACK TO BASICS!

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BACKGROUND

Managing relationships with the customer is not a new concept. The idea has been around and practised by many people for more than three decades (Bodoric, Craig, & Jutla, 2001; Berkowitz, 2000). From the 1960s, management gurus such as Peter Drucker, began preaching the CRM concept by saying that the true business of every company is getting and keeping customers (Anton, 1996). The basis of customer focus evolved through a number of phases. The first phase came after the industrial revolution, where people were introduced to mass production and mass product marketing. At the time, the aim was to direct the customer to use the products. This is called product-oriented marketing (Budijanto, 2001). As time passed changes in the way businesses approached their customers became more evident and by the 1960s direct marketing was introduced. Based on the principles of mass marketing, direct marketing usually focused on selling a mass-product. It involved communicating with large numbers of consumers and inviting them to respond to the promotion by ordering the product through the mail (Dyche, 2002).

In the 1970s, business trends shifted to manufacturing and the term customer satisfaction was introduced (Budijanto, 2001). At the same time, the trend in marketing shifted from direct marketing to target marketing (Dyche, 2002). And as business trends continued to evolve the 1980s brought about businesses that started to focus on product quality as a way of achieving a competitive advantage (Budijanto, 2001; Burchett, 2000). The term Total Quality Management (TQM) was introduced and spearheaded by Demming and Juran (Bounds, York, Adams, & Ranney, 1994). Although TQM focused on producing quality products it was also very customer focused. A major theme of quality management is that customer is the arbiter of quality (Bounds, et al; Massnick, 1997). In the late 1980s, the concept of maximizing customer relationships emerged as a competitive differentiator (Kalakota and Robinson, 2001).

In the early 1990s, Hammer and Champy (1994) mentioned the need for customer-centric business models and by the late 1990s the term relationship marketing was introduced, followed by CRM and one-to-one marketing (Dyche 2002; Berkowitz, 2000; Budijanto, 2001). Since then, CRM has been one of the main areas of concentration for many researchers and business practices. And as new technologies emerge companies are better equipped to implement those ideas related to excellence in managing customer relationships, hence the current re-interest in CRM.

CRM DEFINITION

With so much ambiguity and misunderstanding, finding consensus over the definition of CRM is not an easy task (Boxwell, 2000). However, there is a common thread that does arise. The definitions all include business activities that revolve around the customer. From several definitions offered in the literature, a CRM definition can be variously viewed from a marketing and customer service perspective that works in conjunction with technology, and a business strategy perspective. In respect to the marketing and customer service perspective CRM is defined with the emphasis on customer and their lifecycle. The customer lifecycle, as Kalakota and Robinson (2001) states, is described to have three phases, acquiring, enhancing, and retaining. Proponents of this perspective include researchers such as Bradshaw and Brash (2000), Galbreath (1999) and Newell (2000).

Bradshaw and Brash (2000) state CRM is: "*A management approach that enables organizations to identify, attract and increase retention of profitable customers, by managing relationships with them.*"

Galbreath (1999) gives a more detailed definition by saying that "*Activities an enterprise performs to identify, select, acquire, develop, and retain increasingly loyal* *and profitable customers. It integrates sales, marketing, and service functions through business process automation, technology solutions and information resources to maximize each customer contact. CRM facilitates the relationship among enterprises, their customers, business partners, suppliers as well as employees.*"

Business strategy perspectives focus more on the business approach and free the term CRM from any technological underpinnings, thus giving lesser attention to specific customer management techniques. This perspective describes CRM as an integrated strategy that seeks to compete successfully in the market by acquiring customer loyalty and increasing the company's profitability.

Khirallah (2000) supports this perspective by defining CRM as "*A business strategy that attempts to ensure every customer interaction is appropriate, relevant, and consistent - regardless of the communication channel.*"

Kalakota and Robinson (2001) add to this by focusing on the integration of each business function throughout the enterprise. They interpret CRM as "*An integrated sales, marketing, and service strategy that precludes lone showmanship and that depends on coordinated enterprise-wide action.*"

Reed (1999) maintains that the aim of CRM strategy is to provide a path to increasing a company's profit. For the purpose of this paper, CRM will be taken to mean a strategy that identifies profitable customers, retains customer loyalty and maintains the relationship with these customers by giving them superior and personalized experiences consistently, regardless of the communication channel. The aim is to build customer loyalty, raise retention rates and therefore increase profitability.

CRM IN THE WORLD OF STRATEGIC MANAGEMENT

The concept of strategic management has captured a good deal of attention since the 1960s where Kenneth R. Andrews articulated the need for a holistic way of thinking about an enterprise (Porter, 1991). It is becoming more critical today where businesses all over the world face growing competition through globalisation, increased market complexity, escalated customer demands and expectations, as well as advanced technology (Porter and Montgomery, 1991; Burchett, 2000; Kumar, Pleasance, Rooney, Schmitgen, and Yulinski, 2000). Today's competitive environment has become more intense than ever before. Therefore, it is crucial for businesses to have an effective strategy in order to prevail in competition (Porter, 1996).

What exactly is strategy? There is no single universally accepted definition (Mintzberg & Quinn, 1991). According to Porter (1996), strategy is the creation of a unique and valuable position involving a different set of activities. Mintzberg & Quinn (1991) define strategy as a pattern or plan that integrates an organization's major goals, policies, and action sequences into a cohesive whole. Mintzberg (1991), has further broadened the term by saying that strategy can be seen as a plan, ploy, pattern, position, perspective, or an integration of them and is not only used to deal with competitors but also as an instrument for the collective organization's perception and action. It is a challenge therefore for management to concoct a strategy that is suitable for their organization.

Competitive advantage

The essence of strategy formulation is coping with competition (Porter, 1985). According to Porter (1985), in order to prevail in competition, there are three types of competitive strategies, each with different ground rules. One is cost advantages, whereby a company can sell at a much lower cost than its competition. A second type is product differentiation, whereby a company offers a different mix of product features such as service and quality. The third type is specialization in only one niche of the market, distinguishing itself by unusual cost or product feature. This strategy is called focus.

Given the condition of today's business environment, it is a challenge for businesses to be able to keep their competitive edge (Gordon, 1998). However, with the availability of advanced technology, access to information is easier than ever before. For example, due in part to advances in communications capabilities—such as the widespread use of email, which enables the instantaneous exchange of engineering plans and technical documents—manufacturing and technology companies are able to match competitors' offerings in a fraction of the time required just a decade ago. Moreover, easy access to extensive online information also enables companies to quickly learn about their competitors' pricing moves. In this type of environment, the only points of differentiation are service and quality customer relationship (Connellan and Zemke, 2001; Anton, 1996). This is where CRM takes center stage as a strategy for a competitive advantage (Galbreath and Rogers, 1999; Anton, 1996, Foss and Stone, 2001).

Customer Management

Customer management affects business performance, especially in competitive market conditions. When margin pressures increase, the focus of businesses often becomes myopic thus leading to a focus on short-term financial measures. They start losing their focus on customer management and good customer service to reduce cost, shifting their focus on to productivity. Yet what businesses should understand is the essence of good customer management and its impact on business performance (Foss and Stone, 2001). There is a positive correlation between good business performance and good customer management. Conversely, companies with poor customer management practices are likely to give poor business performance. Therefore it is essential for businesses to maintain good customer management to enhance their business performance.

Customer management is more than managing customer data. It includes the ability to understand customers, analyse their behaviours, preferences, and ensure that each customer receives products or services that match their needs and preferences (Gofton, 2000). Conway and Fitzpatrick (1999) believe that customer management helps organizations think clearly about the customers and the value derived from each customer segment. Foss and Stone (2001) elaborate further and argue that customer management starts with understanding the value, behaviour, and attitudes of different customers and customer groups. The focus on value can best be defined by profitability or margin; it can be measured in terms of actual value (database), realistic potential value (database or research) and future or strategic value (customer is in a segment which is, for instance, increasing in value). Behaviour analysis analyses the retention performance for different customer values. And attitudes analyses the attitude of the customer towards certain products or services. The understanding derived from customer data analysis will help businesses to identify groups or segments of customers who should be managed. As a result, businesses will be able to define the proposition of each of the segments and plan the appropriate value-based offers.

Relationship Management

One of the main tenets of a CRM strategy is managing the relationship with the customer. Companies have long been advised to consider the lifetime value of their customers and to develop strategies for managing customer satisfaction and loyalty in relationships. Managing relationships can be defined as the on-going process of identifying and creating new value with individual customers and then sharing the benefits of this over the lifetime of a company. It involves the understanding, focusing and management of on-going collaboration between suppliers and selected customers for mutual value creation and sharing through interdependence and organizational alignment (Gordon, 1998). Continuous bi-directional communication and interaction are involved. The relationship can be short-term or long-term, continuous or discrete, and repeating or one-time. Moreover, it can be attitudinal or behavioural (Byun and Gray, 2001). Additionally, Morgan (2000) holds that the central foundations for a relationship that includes customer loyalty are trust and commitment.

Trust: Trust is an important aspect in human interactions. It refers to the degree of confidence one feels in a relationship (Grossman, 1998). The concept of trust is distinguished into two perspectives: generalized expectancy and a behavioural conceptualisation of trust (Singh and Sirdeshmukh, 2000). Trust as expectancy may be based on previous experiences while the behavioural conceptualisation of trust refers to consumers' behavioural tendencies towards the service or product provider (Liljander & Roos, 2000).

Commitment: Morgan (2000) defined commitment as an ongoing relationship with another that is so important as to warrant maximum efforts at maintaining it. A study by Barksdale, Johnson and Munshik (1997) in a health care setting, supports affective commitment as the best predictor of return intentions, while continuance and obligation commitment showed no effect. A committed customer has an affective attachment to the service or product provider and shows it by loyal behaviour (Liljander & Roos, 2000).

CRM strategy

As stated before managing relationships is a company's strategy in maintaining the ongoing dialogue with its customers, learning from every interaction, customizing customer treatment, and strengthening the bond between the customer and the company (Newell, 2000), while managing customers is the process of analysing the customer, customer values, as well as their preferences, and behaviours to build a more intimate relationship by offering products and services tailored to their individual preferences (Dang, 2000). CRM can be seen as a strategy that compromises both customer management and relationship management within the organizations. As Foss and Stone (2001) summarize it, a central activity in CRM strategy is utilizing customer insight and information to create profitable customer relationships.

CRM AS PART OF BUSINESS STRATEGY

Many businesses agree upon the importance of CRM as a strategy, however studies show that many of them do not truly understand the underlying concept of CRM itself (Gofton, 2000 as cited by Dang, 2000). They believe that CRM is simply an investment in technology to achieve greater customer satisfaction and revenue growth (Brown, 2000 as cited by Dang, 2000). CRM is not a technology. It is a part of business strategy used in competitive environments that combines all functions within the organization in an effort to maintain relationship with its customers (Menconi, 2000; Shahnam, 1999; Caretzky, 2000, as cited by Dang, 2000). Technology is needed to implement CRM, however, it is not the driver of CRM, nor is it the solution to successful CRM implementation (Khera, 2000).

CRM IN THE CUSTOMER-CENTRIC STRATEGY

Customer-Focus

The basic concept of customer-centric strategy is to focus on the customers. As Drucker (1979) said, the business of business is getting and keeping customers. Traditionally, companies have focused on winning, rather than retaining customers. A dominating market share was typically translated into production economies of scale and the ability to become a low cost producer. The goal was to continually feed the funnel with additional customers, grow market share, and replace those customers who defected to competitors. However, with today's competitive environment and the fact that retaining customers is much less expensive than acquiring a new one, for most organizations where the cost of acquisition is high, keeping customers can be a more profitable strategy (Reichheld, 1996).

Customer loyalty

Many researchers agree that customer loyalty can be described in two distinct ways, loyalty as an attitude and loyalty as behaviour. Loyalty as an attitude refers to individual feelings and emotions that are attached to products, services, or organizations. This approach is linked to customer satisfaction. Loyalty as behaviour, on the other hand, is based on the customer's intended or actual purchase behaviour. This approach refers to customer-perceived value (Jacoby and Kyner, 1973; Fornier, 1994; Yi, 1990, as cited by

Hallowell, 1996). The importance of customer loyalty for businesses is emphasized by the analysis that reveals a positive correlation between customer loyalty and business profitability (Hallowell, 1996). Reichheld (1996) argues that increasing customer retention by a mere 5 percent led to increases in profitability of 25 to 85 percent. Moreover, doing business with continuing customers will lower customer-price sensitivity and cost of advertising to entice new customers (Reichheld and Sassers, 1990). Given the facts mentioned above, understanding how or why a sense of loyalty develops in customers becomes one of the crucial management issues of today (Pritchard, Havitz & Howard, 1999, as cited by Too, Souchon & Thirkell, 2001). As a result, many businesses today are shifting their strategy and focusing more on gaining and maintaining customer retention and loyalty.

Customer Satisfaction

Customer satisfaction is a mental state that results from the customer's comparison of expectations prior to a purchase with performance perceptions after a purchase (Oliver 1993, Oliver 1996, Westbrook & Oliver 1991 as cited by Soderlun and Vilgon, 1999). Much of the literature proposes that customer satisfaction influences customer loyalty. Proponents of this theory include researchers such as Anderson, Fornell and Lehmannl (1994); Gummesson (1993); Reichald and Sasser (1990). These researchers discuss the links between satisfaction, loyalty and profitability and argue that customer satisfaction is necessary in gaining customer loyalty. However, customer satisfaction alone is not a predictor of customer loyalty (Foster, 2000). Several studies performed revealed: Even with all the attention given to customer satisfaction, on average, US-based companies lose over half their customers every years (Reichheld, 1996). In a study of 20 companies in US, customer satisfaction increased in all companies yet customer retention levels remained the same or actually decreased (Reese, 1996 as cited by Miller-Williams Inc., 2001). Many researchers argue that customer satisfaction measures only past experience, not the customer's intention (Miller-Williams Inc., 2001). Therefore, it fails to predict how customers will actually behave (Foster, 2000). And while customer satisfaction is important to any successful business, many studies have shown that satisfaction alone is not enough to build a loyal customer base (Doss, 2000). Another element that said to be a better predictor of customer loyalty is customer-perceived value (Brandt, 2000; Gardner, 2001).

Customer-perceived value

Customer-perceived value is the market's evaluation of all of the benefits and costs of using a product as compared to alternatives (Insight Management Advisory Service, 1999). The marketing literature suggests that creating superior value for customers is one of the ways to win loyalty (Oliver 1996). In this view, customer perceived-value is seen as part of a hierarchy that links variables affected by managerial decisions, such as pricing, levels of advertising, product features and distribution, to customers' behaviour responses, such as word-of-mouth communication and re-purchase (Oliver 1996). Some researchers interpret customer perceived value as a price-quality trade-off (Dodds, Monroe and Grewal, 1991; Anton, 1996). Some argue that perceptions of value go beyond just a price and quality trade-off, unless quality is defined in an all-encompassing manner to include everything other than price. Even though there are many perspectives of how to measure customer-perceived value, they all agree that the resultants of customer-perceived value, in turn, will influence customers' purchase behaviour (Bolton and Drew, 1991). To gain customer loyalty, businesses today need to create a superior customer-perceived value that motivates the customer to repurchase. However, creating a superior customer-perceived value is a not a simple task. It needs a holistic view of the customers and the way businesses can fulfill the customers' needs (Foster, 2000). Moreover, real customer-perceived value is established by repeatedly delivering what a customer expects regardless of the delivery channels (Dick & Basu, 1994).

Maintaining customer retention and loyalty

Loyalty is a complex topic that warrants a multifaceted conceptualisation (Dick & Basu, 1994). Based on the generally accepted notion that customer loyalty is important, many businesses centralize their resources on continually improving core products and services (Bhattty, et al., 2001). However, while these factors are necessary for customer attraction, they are not sufficient for maintaining true customer loyalty (Bhatty, et al., 2001). Therefore to sustain customer loyalty, businesses should create barrier strategies that prevent customers from switching to competitors (McQuitty, Finn & Wiley, 2000; Bhatty, et al., 2001). According to several studies (Bhatty, et.al, 2001; Calhoun, 2001; Foster, 2000), two such strategies are creating a seamless customer experience and building a strong relationship between the customer and the business.

Seamless customer experience: A seamless customer experience is achieved when a consumer interacts with a company across multiple channels without experiencing dissonance during the whole purchasing process (Cersosimo et al, 2000). Cersosimo et al. (2000) analyse it further and argue that a seamless customer experience encompasses two dimensions: the process and the channel. The seamless process experience enables a customer to experience total integration of the different steps involved in the interaction process, while the seamless channel experience provides coherence among all available customer touch points (Cersosimo, et.al, 2000; Barracliffe & Taylor, 2001). Thus, the whole experience and what happens during interactions between customer and business have a major impact on creating loyalty (Cersosimo et. al, 2000). Although this may seem simple, from the company perspective, creating a seamless customer experience by synchronizing all aspects of its activities creates a number of difficulties. According to Cersosimo et al (2000), these difficulties include the redesign of existing organizational structure, coordination of information systems and technology, management of multi-channel of communication, appropriate selection of human capital, consistent application of pricing strategy, effective inventory management and selection of product assortment across channels.

Strong customer relationship: Bhatty et al (2001) in their study on customer loyalty, find that strong relationships between customer and a business are critical to build customer loyalty. They believe that a strong relationship can create a barrier that keeps the customer from switching to a competitor. A strong relationship is based on meeting customers' expectations over a period of time, and thereby gaining the customers' trust.

CRM as part of Customer-Centric strategy

From different points of view on how to gain customer loyalty, there is one common issue. Anton (1996) says that to provide performance that exceeds customer expectation, the company must first know what the customer needs and wants. However, customers are not equally profitable for a business and to be able to satisfy all of the customers is practically impossible. Therefore, it is important for businesses to know which customers are the most profitable for them. By understanding customers and their value, a business can not only efficiently allocate resources to its customers, but also be able to focus on developing long-term customer relationships (McDougall, Wyner, & Vazdauskas, 1996). The facts given above show that understanding customer data is important for company's success. However, in reality, organizing and interpreting customer data can be a complex and difficult task. Therefore, it is essential for businesses to have effective customer management (Crosby & Johnson, 2000).

As mentioned previously, to be able to provide a consistent and seamless experience to customers, businesses should manage and integrate all the channels and possible customer contact so that they can present a consistent manner to customers (Peppard, 2000). However, delivering consistent positive experience throughout all channels can become very challenging when you realize that one size will not fit all (Conway & Fitzpatrick, 1999). Therefore, effective relationship management practice is an important building block for maintaining customer loyalty (Bhatty, et.al, 2001; Calhoun, 2001; Foster, 2000). Crosby and Johnson (2000) emphasize the point that CRM is about developing proactive customer and relationship strategies that support the desired customer experience and build profitable customer loyalty for the organization.

MANAGING BUSINESS PROCESS IN CUSTOMER-CENTRIC-MODEL

Integration issue

As mentioned before, to be able to provide a seamless experience to customers, businesses should manage and integrate all the channels and possible customer contact so that they can present a consistent manner to costumers (Cersosimo, et al, 2000; Barracliffe & Taylor, 2001). A company can be seen as an integration of multifunctional, multidisciplined workgroups, each with a purpose and a product or service to provide to the customer (Anton, 1996). Sawhney (2001) elaborates on this issue further by saying that many companies have a fragmented view of customer information that is scattered across multiple applications and databases used by different departments. Moreover, each workgroup or business unit has different strategic and product imperatives and different functions sometimes rely on different kinds of employees with different skills and ways of working. As a result, there is a situation where different parts of the company end up selling to the same customers, or competing for the same business without even knowing it (Sawhney, 2001; Anton, 1996). A survey conducted by Forrester Research (Ernst & Young, 2000) of over sixty companies shows that only: 48% of firms know about a problem before a customer does, 43% alter service based on a customer's profitability, 42% would sell something during a service call, 37% know if they share a customer with another division, 20% know if a customer has visited the Web site, and 23% of telephone agents can see customers Web activity. Given these facts, managing customer points of contact is essential to create a seamless customer experience.

Identify customer touch-point

Customer touch-point, a point where company and customer interact, is important. To be able to manage the customer touch-point, it is important to identify the points where a company interacts with its customer, both internal and external, and identify the processes in which a customer can subjectively measure a company's ability to deliver to the level expected by the customer (Anton, 1996).

Channel management

The aim of managing the channel is to ensure that the most effective method is used to distribute or deliver the information, product or service (Brown, 2000). In order to be able to provide an experience that exceeds customer expectations, the delivery channel must be viewed in terms of appropriateness to the task that the customer wants to perform (Teo, 2001). One of the key areas within the channel management strategy is channel integration (Teo, 2001). Channel integration is concerned with providing a common consolidated and real time view of the customer across all channels (Ernst & Young, 2000). A customer may interact with a business through different channels. To be able to create a seamless experience to the customer, businesses should manage the customer's point of contact so that all the necessary information required to complete the transaction is available in a consistent manner at each point of interaction (Peppard, 2000).

THE VALUE PROPOSITION OF CRM

The value proposition of CRM as enumerated by Goldenberg (1998, as cited by Teo, 2001; Brown, 2000, as cited by Budijanto, 2001), can be categorised into three areas: revenue enhancement, cost reduction and the strategic impact. In addition to these economic drivers, there are intangible, non-economic drivers, which make a significant contribution such as increase customer satisfaction and long-term reputation (Dang, 2000). These value propositions will lead to a company's ability to sustain its competitive advantage (Boxwell, 2000).

Revenue enhancement

According to Brown (2000), many CRM benefits come from sales revenue and margins, which leads to profitable and sustainable growth. Teo, (2001) analyses it further and finds that some of the revenue drivers are:

Up-selling potential: Up selling is defined as a customer buying more from the same supplier, usually the same product or service (Brewer, 2001). Implementing CRM strategy can incrementally increase company's revenue by selling upgraded, higher margin services or products to existing customers (Brewer, 2001)

Cross-selling potential: Cross selling is defined as a customer buying a new, different product from the same supplier as opposed to buying from an alternative source. By analyzing customers' behaviour and their transaction history, businesses can predict their interest and therefore can offer products that match customer's need and interest (Brown, 2000).

Customer retention: Brewer (2001) states that a 20 percent increase in the customer retention rate would improve the profit of a company by 120 percent. Reichheld and Sassers (1999) claimed that improved customer retention of 5 percent would improve a company's profit by 25 to 95 percent. Even though these percentage estimations are different, they both show that improved customer retention would result in significant improvement in company's profit.

Cost Reduction

CRM implementation can benefit companies in reducing several business costs (Budijanto, 2001). Some of them are as follows:

Reduced operational cost: By effectively implementing CRM strategy, businesses can reduce cost in many areas including order entry, distribution, customer inquiry handling; even bad debt may be reduced. Brown (2000) mentioned that as a company offers customers more contact channels, managing these channels would reduce direct sales cost.

Reduced marketing costs: According to Conway and Fitzpatrick (1999, as cited by Budijanto, 2001), the use of accurate and integrated customer data would eliminate redundancy in marketing activities. By implementing CRM strategy, a company would be able to target specific customers. Therefore, the cost of a marketing campaign could be reduced (Budijanto, 2001).

Strategy impact

CRM implementation aims to gain customer retention and loyalty. Studies have shown that customer retention has a positive correlation with customer profitability and market share (Anton, 1996). Teo (2001) believes that CRM also affects business strategy in the following area:

- The ability to perform enhanced levels of service quality and improve customer satisfaction and loyalty.
- The ability to cross-sell other types of products to the customers.
- The ability to reduce time to penetrate market by allowing effective introduction of new products and services.
- The ability to customize products and service to meet customers' needs.

TECHNOLOGY AS A CRM ENABLER

As customer numbers increase and companies become larger and more remote from the customer, technology becomes increasingly important to CRM strategy. It enables organizations to build powerful personal relationships with their customers and their needs by using database and data warehouses (Foss and Stone, 2001). From a business standpoint, technology allows organizations to build detailed customer profiles that facilitate precise matching of marketing offers to prospective customers and further it can be used to track the effectiveness of marketing programs, as well as providing the basis for future planning (Shani & Chalasani, 1992). In effect, technology can integrate the enterprise, fostering an environment of shared customer knowledge and direct the right employees to serve the right customers (Galbreath and Rogers, 1999).

From a customer's perspective, technology can be used to benefit selected customers by tailoring a product/service to them specifically or in micro-segments. Moreover, technology can help companies provide personalized after-sales service and support based on customer profile data. In addition, integrated technology enables customers to have a highly consistent view of an enterprise, regardless of the method or channel used (Cayenta, 2001). As a result, this will add to the value of the product/service and can lead to greater loyalty (Galbreath & Rogers, 1999).

CONCLUSION

In an increasingly competitive marketplace, companies need to have a strategy to retain existing customers and acquire new ones. Many studies show that in today's business environment, where product and price are no longer a point of differentiation, the only points of differentiation are service and quality customer relationships. Managing the customer and their relationship with the company are two strategies used by businesses in order to prevail in a competitive environment. And Customer Relationship Management is a viable course of action for striking a balance between both strategies. CRM produces results where other means have failed or not produced equal results. And rather than being dependent on other factors, CRM can support different strategic implementations. Nowhere is this more evident than with technology. Many companies see technology as "the way to go", neglecting the importance of customer service. Or they believe if one has technology than it equals customer service. Although technology enables quicker more efficient customer service, it by no way replaces it. Technology is only an enhancer to a foundation that lies in Customer Relationship Management.

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24

VIRTUAL COLLABORATIVE IMPLEMENTATION FOR SIMULATION BASED ACQUISITION

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INTRODUCTION

Of critical importance to most contemporary organizations are three primary objectives: (a) shrinking overall product development life cycles (DLCs), (b) reducing development (and design) costs, and (c) maximizing product utility and value while functioning within cost and budget limitations and operational constraints. The first objective is important because "missing the market" (or being operational delayed) may have irreparable consequences for those who produce new automotive lines, commercial aircraft, and military systems. Reducing costs, the second objective and a byproduct of the first, is part of the pervasive need for more efficiency (productivity) in organizational operations. The third objective, the creation of utility has value implications and is of special importance to customers and system users.

To accomplish the above objectives, many organizations have moved away from serial to concurrent collaboration through the use of cross-functional, integrated product teams (IPTs) and the use of virtual collaborative environments (VCEs). The latter enabling technology includes the use of 3D computer graphic systems that create realistic product and system displays for use by individuals and integrated product teams (IPTs). These systems give participant the feeling of viewing a real model and of being part of a real environment even though they are in a computer-simulated "world." VCEs provide images almost as realistic as physical prototypes, and offer the capability to rapidly change perspectives and views of synthetic system and product models–even full scale (1-to-1).

Will, 1991 and Harrison *et al.,* 1996 report that profit-making, private sector organizations are now using VCE tools to improve their product design, development, and manufacturing processes. Further, Will, 1991 reports that these applications have evolved from earlier developments in modeling and simulation (M&S) to use for VCE industrial design and development. Specific examples, according to Keller, 1998 include Boeing for its 777 aircraft non-prototype creation, and DaimlerChrysler for its Dodge Intrepid product line and engine development. Also reported by Lehner and DeFanti, 1997, Smith and Pawlicki, 2000, and Smith, 2001 is that General Motors (GM) routinely reviews static vehicle concept models in various environmental settings and performs virtual new vehicle comparisons to current models. In addition, Banerjee *et al.,* 2002 indicates that Caterpillar Inc. now uses VCEs to develop and display new tractor designs and dynamic features.

On a broader scale, to overcome the high cost and duration of military design, development, and system life cycle times and the limitations of traditional system acquisition practices, the U.S. Department of Defense (DoD), as reported by Kern and Purdy, 1999 and Purdy, 2001, has developed and adopted a strategic technology and innovation management initiative called Simulation Based Acquisition (SBA). This integrative process is designed to promote the rapid and more economical development of quality military systems through the use of computer-based M&S and IPTs. Implementation objectives of this initiative are to encourage and support iterative, cross-functional team collaboration, and early system evaluations. Kern and Purdy, 1999 and Truelove and Donlin, 2001 go on to say that in a similar vein, the U.S. Army has launched the Simulation and Modeling in Acquisition, Requirements, and Training (SMART) Program to fully include and integrate all of its stakeholders (operational users, program managers, contractors, testers, trainers, maintainers, and logisticians) into the Army's modernization efforts. Important enablers in SMART implementation are the Warren, Michigan based Tank Automotive Research, Development and Engineering Center (TARDEC) and its National Automotive Center (NAC).

The remainder of this paper and study report describes: the research methodology used, an IPT/VCE conceptual model, VCE technologies and systems, investigations and results, VCE applications and advantages, and a summary and conclusions.

RESEARCH METHODOLOGY

The findings and conclusions presented in this case study are based on a five-year and continuing research and development effort involving the authors and others. The ultimate objective was to develop and implement an advanced collaborative environment (ACE) that could be used to satisfy SBA and SMART goals and objectives. Diverse discipline areas included in an initial literature review were: engineering and project management, individual and organizational behavior, information technologies, computer supported collaborative work (CSCW), and virtual reality (VR). The literature review and interviews with users (present and future customers), subject matter experts, and technologists resulted in the development of a conceptual model that includes various parameters and interrelationships important to program and project management and IPT members working in a VCE modality. VR system and VCE technology empirical and usability tests were conducted that focused on several model parameters, and the identification of applications and lessons learned internally and from other organizations. Literature searches, test data and results, and case study information were then analyzed and integrated to determine if the developed conceptual IPT/VCE framework and its parameters and interrelations could be supported or refuted. Finally, user interviews were conducted to validate the conceptual model, the use of VCEs for design and development, and the ACE concept. From these process activities, integrated IPT and VCE applications and advantages were identified.

IPT/VCE CONCEPTUAL MODEL

The conceptual model, shown in Figure 1, [adapted and modified from Newman and Lamming (1995) and Preece (1994)] illustrates the interrelationships between people, work, and technology within the broader context of organizational, social, and technical environments. Selecting an appropriate tool or integrating advanced technologies to support the tasks of team product design evaluation and development requires that all model elements be considered individually and collectively. While this can be considered a general model, this paper focuses on how certain elements relate to and affect the use of VCEs by IPTs.

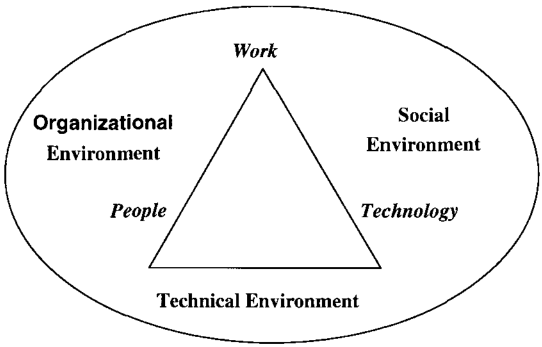

Figure 1. A conceptual IPT/VCE model

ORGANIZATIONAL, SOCIAL, AND TECHNICAL ENVIRONMENTS

There are several environments that drive and influence all activities and tasks within organizations and the DLC process. As shown in Figure 1, these environments are: organizational, social, and technical. The organizational environment is primarily defined by the goals and objectives of the organization–whether profit seeking or not. The social environment is determined by how the organization functions with regard to individual and team interaction, cohesiveness, and motivation to accomplish work. The structure of the organization, e.g., functional, project, or matrix, affects the social context of activities performed. The technical environment is driven by the degree to which the organization supports and is dependent on technology. An organization's degree of technical orientation and dependency can lie anywhere on a continuum between highly innovative and technology (risk) averse.

These environments by themselves and jointly, influence a set of factors that directly affect IPT DLC activities. As illustrated in Figure 1, these elements are work, people, and technology. Within these factors, important are the relationships between people and the work tasks they perform, and between people and the technology they use to accomplish work.

Work: Product Design and Development

In many contemporary organizations, product design and development are major objectives and reasons for the existence of certain organizational elements and IPTs. Ulrich and Eppinger (1995) have characterized product creation as a systematic method of evolving a product from idea conception to product release to customers. They indicate that the process begins with concept development, and progresses through system level design, detailed design, testing and refinement, and production ramp-up. Current product development practices seek to reduce overall system DLC times through the use of concurrent engineering and multi-functional and empowered IPTs. Usually required are flexible leadership, frequent design iterations, simulations, and extensive testing.

Resources used, development time and cost, time-to-market, and resultant product quality are used by many organizations to measure and assess performance and success in product development. Two important metrics, overall product costs and time-to-market, are dominated by decisions made in the early stages of the design process. Will (1991) estimates that 85% of product development costs are determined before the product design is released to manufacturing. Garcia *et al.* (1994) also estimate that by the time 10% of total project funds are expended, approximately 90% of a product's development costs are established. In other words, most cost (and schedule) determining decisions in product development efforts occur early in the DLC–during the design phase.

As should be evident, design errors detected and corrected during early design activities have the highest likelihood of reducing overall product or systems costs and time-to-market since *it is easier to change electrons (i.e. electronic drawings) than atoms (i.e. physical systems).* During this early DLC phase, planning and design decisions are made to identify and reduce risk and improve total product quality. Because of the cost implications involved in early design activities, organizations need to select systems and methods that provide cross-functional design IPTs with the best decision support tools available.

People: Integrated Product Teams

Shu and Flowers (1994) indicate that traditional methods of system and product design, development, and acquisition have often been described as serial and linear processes where functional groups make contributions sometimes independent of other internal and external elements. As a result of these "throw it over the wall" activities, critical decisions that can significantly impact overall product design, development, and costs are frequently made without regard to the effect on or consequences to others.

Samsone and Singer (1992) state that the basic requirement of concurrent engineering, needed for product design and development, is to assemble a team that is focused on developing or redesigning a product. They go on to say that these teams are usually composed of people from various functional elements, e.g., development, engineering, manufacturing, and product management. Juran and Gryna (1993) believe that concurrent engineering is not a set of techniques, but a conceptual methodology that enables all who are impacted by the product design have early access to design information, and have the ability to influence the final design to identify and prevent future problems.

Within these cooperative environments it is necessary for individuals to share information and collaborate in the decision making process. Several researchers and authors including Dhar and Olson (1989), Garcia *et al.* (1994), and Dieter (2000) indicate that collaborative work requires the exchange of information for purposes such as notification and clarification, and the processing of information for monitoring, negotiating, and decision-making. This cooperation ensures that everyone impacted by the design has early access to design information and the ability to influence the final design effectively and efficiently. Collaboration is the key to make this happen. Unfortunately, in spite of the vast body of collaborative work data collected over the last half century, an underlying theory of collaboration does not presently exist–let alone one that relates to VCEs.

For the above reasons, a need exists to develop tools that support concurrent engineering and cross-functional design team interactivity by providing individuals and teams with accessibility to design data and information regarding product versions and customer needs. To improve the probability of product development success, these tools should allow teams to interact face-to-face and make decisions from multiple perspectives in a shared information space, sometimes at distributed (networked) locations, using the best and most current information.

Technology: Immersive, Interactive VCE Tools

Frequently, there is a need to change views in a product or system development environment. A commonly used method includes manipulating Computer Aided Design

(CAD) images. Within a CAD environment, views can be rotated, reduced, enlarged, or changed fairly easily. However, usually only reduced scale (scaled down) images are available in these systems. The VCE is different from traditional two-dimensional (2D) paper or 3D electronic CAD drawing review environments because it provides and supports users with full-scale (1-to-1) system or product views. Within a 3D VCE, numerous navigation and viewing perspectives (on top of, beside, underneath, inside of) perspectives are possible. These systems and their interface devices also provide a capability for 3D, real time image reorientation.

Various VCE systems technologies and systems, discussed in the next section of this paper, are available to implement 3D and real time viewing of product models. Some have multisensory capabilities that support visual, audio (including directional sound), direct object manipulation, and touch. Important to VCE users are the sensations of immersion (being surrounded in an environment) and presence (feeling you are in one place while actually being in another). Both occur in some degree in all VCEs.

With the conceptual model and its parameters and interrelations in mind, the next section identifies and briefly discusses product design technologies and two commercially available VCE systems and their features. These systems, individually and together, are presently being used by several public and private sector organizations to support various phases of their DLC and IPT activities. Also, presented is a description of an advanced collaborative environment (ACE) developed and successfully used by operational IPTs.

VCE TECHNOLOGIES AND SYSTEMS

VCE Systems

Computer technology has had a pervasive and significant impact on the total product design and development process. In the past, products were first created using pencil and paper drawings that only represented 2D product views. Today, product concepts are routinely initiated by developing 2D and 3D solid models of alternative designs using computers. CAD technology enhances the productivity of a single designer, but is not very productive or effective in a collaborative group design or development review settings. VCEs are a family of integrated technologies that are being used to support the needs of today's IPT DLC processes. These systems leverage commercial technologies to facilitate collaboration between relevant stakeholders and to greatly reduced reliance on hardware mockups and prototypes.

A VCE is a suite of 3D (virtual reality or VR) graphics, simulation tools, displays, and supporting software programs that allow users to operate *within* a computer-generated environment on an interactive real-time basis–and even at distributed, remote locations. In some organizations, VCEs are being accepted as a general business tool. For example, in the commercial automotive industry, the use of traditional clay models and physical prototypes is costly. Using VCE systems, a team can visualize and interact with "complete" virtual vehicle prototypes consisting of assemblies, sub-assemblies, or components in 3D and explore new products, plans, and concepts long before they exist in reality. Participants meet in a virtual showroom setting to review a combination of styling, packaging, and engineering aspects of a proposed vehicle. Smith *et al.* (2000) and Smith (2001) report that in order to substitute for physical prototypes, virtual models must provide high-fidelity renditions of vehicles, contain physical and functional features like shininess (highlights, color, reflections), support contour changes (i.e. flexible parts), and have the capability to open and close a virtual door.

As part of a continuous improvement strategy, numerous commercial organizations (e.g., Boeing, GM, DaimlerChrysler, Caterpillar, and the U.S. Army) have purchased advanced VCE systems that they feel better support their DLC time and cost reduction objectives and activities. These systems and their interface devices can be programmed to orient images in real time while review participants remain immersed in the viewing environment. General multi-sensory capabilities include visual, audio (including directional sound), direct manipulation, and touch. This mix accommodates all human senses except taste and smell, which are usually not very important in most product or system developments. Examples of selected system, their features, and capabilities used by the U.S. Army ACE development group are as follows.

CAVE® and WorkWall™ Systems

As part of a continuous improvement strategy of the U.S. Army SMART development and support initiative, purchased were two immersive projection technology display systems–the CAVE Automatic Virtual Environment (CAVE®), and a WorkWall™. Both systems are composed of several stereoscopic projection screens configured as either a room (CAVE) or wall. Smith *et al.* (2000) and Smith (2001) believe from experience at GM that the former is generally regarded as being better suited for views "inside, looking out" and the latter for the perspective of "outside, looking in". Full-scale views are possible and are routinely used. Both systems use Silicon Graphic Inc. (SGI) Onyx® series hardware and Infinity Reality™ software visualization products to couple SGI computers to render a stored model required for DLC applications.

The CAVE is a multi-person, 1,000 cubic foot (10x10x10 ft.) room-sized, high-resolution 3D video and audio environment. Figure 3 reflects the layout of the CAVE system showing the four projectors and mirror systems and their orientations. In operation, users enter the CAVE, stand or sit, and wear electronic stereoscopic glasses to interact and navigate in the 3D virtual world. Pictured in Figure 4 is an engineer reviewing a new concept design in a CAVE (with supporting computers shown on the right). In addition to the projectors and screens, hardware systems include a 3D head-tracking device (to provide a correct perspective), a 3D pointing device, stereo glasses, and audio speakers. The number of participants in the CAVE is limited to the size of the enclosure–with a maximum space limitation of twelve users but practically five. For additional CAVE information see Cruz-Neira *et al.* (1993).

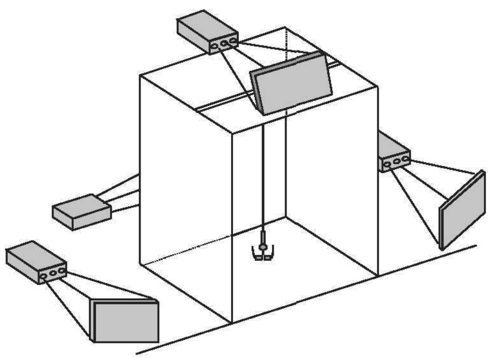

Figure 3. The CAVE® system

Figure 4. The CAVE® environment

The sense of grabbing, touching, or pushing on objects in a VCE are important for applications where the user needs to either operate, manipulate, or move virtual objects in real-time. Two commercial haptic devices, Cyberglove™ and Cybergrasp™, were integrated into the CAVE environment. Figure 5 shows a user (customer) wearing a fully instrumented glove providing 22 joint angle measurements. The Cyberglove™ device has three flexion sensors per finger, four abduction sensors, a palm-arch sensor, and sensors to measure wrist flexion and abduction. The Cybergrasp™ device adds a force feedback capability that allows the user to "grab and feel" computer-generated objects in the VCE.

Figure 5. User with haptic glove interacts with virtual crew station in a CAVE

Additional environment enhancements can be added to the VCE. For example, the commercial physics-based dynamic analysis software DADS™ by LMS International provides capabilities to assemble, analyze, and optimize behavior of dynamic systems. Using such tools, the interior of a transport aircraft can be displayed to evaluate vehicle loading and unloading, and virtual obstacle course testing allows evaluation of vehicle performance and maneuverability.

Similar to the CAVE system in function, a WorkWall™ is a 10 to 21 ft. long by 14 ft. tall rigid flat vertical high-resolution 3D video and audio environment. Models or environments are displayed from floor to ceiling, and views of an infinite number of vehicles, systems, and assemblies are possible. Figure 6 illustrates a commercial aircraft application review. The WorkWall™ system does not use any position and orientation tracking systems and thus does not provide users with as much immersion as the CAVE. However, the lack of head and hand tracking leaves more processing power for improved resolution and minimal system latency (i.e., image delays with change). Most applications of WorkWall™ technology are full-scale reviews of system or subsystem exteriors, which are ideal for group presentations and collaborative design and development reviews and "outside-in" viewing. Each of the above VCE systems uses large projectors and stereoscopic glasses that allow IPT members to individually or collectively view virtual product or system models. In this way multiple viewers share virtual experiences discovery, and ideas.

Figure 6. A WorkWall™ collaborative review

ACE

Use of CAVE and WorkWall CVE systems has provided a quantum leap in IPT DLC capabilities and results achieved. Significant improvements in DLC efficiency and effectiveness have been reported. However, a constraint has been the size of IPTs (sometime up to 120 members) in relation to the physical size limitation of these CVEs. Both systems have physical size limitations–a maximum of 12 participants in the CAVE and about 35 viewing the WorkWall (determined by the size of the review room and number of stereo glasses available). In addition, both systems require specialized CAD image transformation, and VCE hardware, software, and network support–occasionally at remote locations. To overcome these constraints and demands, an expanded VCE capability was needed. However, it was planned that the CAVE and WorkWall would continue to be used by small groups either working as small teams or on a shared basis for activities requiring "inside-out" and "outside-in" views, respectively [consistent with the findings of Smith et al. (2000) and Smith (2001)].

Because of the need for expanded capability, the U.S. Army ACE Group at TACOM, as reported by Bochenek-Broecker and Ciarelli (2001), has established a revolutionary ACE concept and strategic implementation to accommodate large IPTs and to provide distributed, web-based, desktop capabilities for more routine synchronous and asynchronous individual and IPT activities. The focus of this implementation system has been the creation and use of a new and expanded "toolset" consisting of enabling technologies (M&S and VR) *plus* mandatory collaborative interaction (IPTs) *plus* ACE capabilities–in addition to the CAVE and WorkWall when needed. This powerful toolset empowers engineers, soldiers, contractors, testers, maintainers, and others through its connectivity with a real-time, on-demand, 3D life-size immersive virtual environment and a web-based interactive information repository. As designed, ACE provides early, frequent, and concurrent access to the virtual system under review and development so important and perhaps critical issues and problems are identified and resolved early, when changes can be incorporated at reduced cost. Figure 7, adopted from Bochenek-Broecker and Ciarelli (2001), illustrates an overall ACE consisting of VCE view systems (local and remote), web browser views, product data management (PDM) access, distributed product data bases and information sources, and required high capacity and world wide web (WWW) networks. As such, the concept and design supports individual desktop and networked viewing of virtual models and access to PDM data and information.

To provide the functional software support needed for web-based desktop viewing by IPT members, the ACE development group selected Parametric Technology Corporation's (PTC) WebIT framework called Windchill™ as its software PDM core. A Windchill™ ProductView™ program provides data visualization and full-featured viewing capabilities for parts, assemblies, and drawings. These products have been found to be fully compatible with the designed ACE architecture, and with other packages provide a wide range of capabilities and tools for PDM. The products use a web-based architecture that supports functionality for accessibility via standard web interfaces, scalability for a large number of concurrent users, reusability across multiple programs, and extensibility to new domain tools. Application threads support task, performance, and cost analysis as well as systems engineering. In addition, PTC's Pro/ENGINEERING product definition, design, and development platform was selected for ACE use. Other vendor design products, like CATIA™ by Dassault Systemes and Unigraphics by Electronic Data Systems (EDS) are also be fully compatible with Windchill™ through translation functionality.

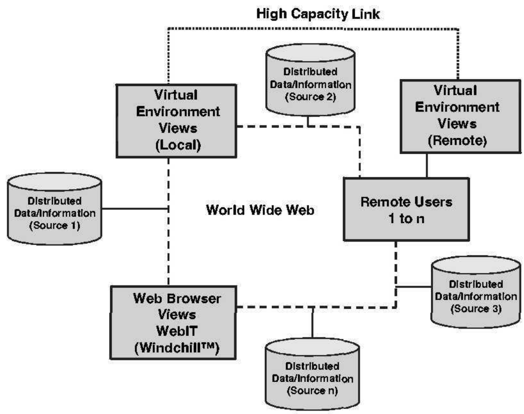

Figure 7. An Advanced Collaborative Environment (ACE)

The architecture needed for an ACE must logically organize product model information and its behaviors. In effect it must serve as a virtual prototyping environment (VPE) structure. With this capability, users in local and distributed locations can analyze the impacts of their decisions over all phases of a DLC. Such a capability must be robust enough to bring together a very diverse range of capabilities for specification identification, engineering design, project management, configuration management and other PDM functionality. Ideally the VPE must tie together many commercial engineering analysis and systems engineering tools as well as the capability to integrate legacy databases and tools. Figure 8 [adopted from Chandha and Welsh (2001)] represents such a modular open architecture needed by an ACE to support standard protocols such as HTML, XML, HLA, Java, and CORBA.

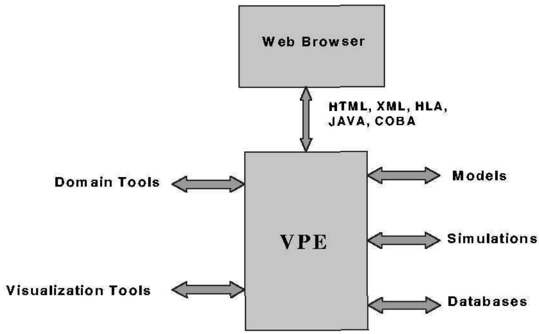

Figure 8. VPE logical architecture

INVESTIGATIONS AND RESULTS

As a result of initial literature search and product reviews, evolutionary empirical and usability testing was accomplished involving the authors at various locations as a precursor to ACE eventual development. These progressive steps were needed to understand the advantages of virtual environments of various sizes and capabilities involving individuals and groups. Test results and findings are as follows.

Early VCE Empirical Testing and Findings

Empirical testing was conducted very early in the ACE development process by the authors to evaluate early first-generation VCE systems for use in a conceptual design review of a new U.S. Army vehicle support system [reference Bochenek (1998) and Bochenek and Ragusa (1998)]. The VCE devices tested were the HMD, Binocular Omni-Orientation Monitor (BOOM), and stereoscopic glasses with monitor that were compared to a monoscopic CRT monitor. These systems are the first VR systems developed and are primarily for individual and small group use. Findings indicated that while there were significant advantages of some VCE technologies during certain phases of the concept design review process, unfortunately *no single VR device* fully satisfied all team activity needs. Further, none of these systems was very satisfactory for group discussion and consensus development, and participants did not want to stay in the VR environment for team discussions but instead preferred face-to-face interfacing.

Because of the limitations found in the testing of first-generation systems and user preferences discovered, an additional literature search was conducted. This review indicated that while large corporations such as GM, Caterpillar Inc., and others are using VR to prototype new products, little empirical testing had occurred according to Lehner and DeFani (1997). Mahdjoubi and Wilshire (2001) report that GM research has focused primarily on assessments of visual simulations and in building and landscape evaluations. Youngblut *et al.* (1996) and Hudson *et al.* (1999) also confirm that, comparisons among different VR devices have been mostly qualitative and limited.

Second-Generation VCE User Evaluations

As a result of the information gathered and testing limitations identified, empirical VCE testing was planned and accomplished using operational U.S. Army users and a CAVE– a second-generation VCE that can support larger IPT activities. This test was designed to compare a traditional method of new concept presentation (i.e., a stand-up briefing using PowerPoint™) with the use of a briefing conducted in a CAVE. Test participants were made up of 40 subjects grouped into eight-five person teams. None had participated in a VCE-based design review before.

Test results were analyzed and reported by Banergee, Bochenek, and Ragusa (2002). Quantitative analysis and findings indicated that participant feelings of immersion (i.e., being surrounded in a virtual environment) correlated positively with presence (i.e., seeming to be in a virtual environment but actually physically being somewhere else), and the use of CAVE as a tool for design review was favored. The high level of presence recorded for the CAVE also supported this fact. However, a weak positive relation between design comprehension and presence was found, but qualitative data analysis clearly indicated that test participant preferred the CAVE to the PowerPoint™ concept presentation. The great majority of users indicated strong support for the CAVE as a future concept review environment. Qualitatively, one participant commented: "The CAVE allowed me to really see ... and better understand the design ... I could touch and feel it around me." Another said, "I can't wait to come back and see and react again to this scenario," and "This is where the future is." Some participants were even observed trying to reach out the touch the virtual model.

ACE Results and Validation

The ACE Group's pioneering partnership with a new vehicle Program Management Office (PMO) has set a standard for future U.S. Army SMART activities. This was the first organization to fully embrace and apply these collaborative technologies to the vehicle development and acquisition process. Since June 2001, ACE has given 500-plus Program Managers (PMs), users (customers), and acquisition professionals virtual access to a family of eleven variant vehicle designs based on a common vehicle structure. The ACE strategy is key to meeting the PMOs aggressive DLC schedule, because it was the *only* way for PMs and stakeholders to make decisions on vehicle designs and meet a year 2008 operational readiness milestone.

More specifically, Bochenek-Broecker and Ciarelli (2001) report that the following qualitative ACE user comments were obtained during ITP activities at TACOM and other user remote test locations. A development Office Director stated, "Seeing a draft requirement function within an operational environment is much better than a large chart presentation." A system developer stated, "Reviewing the designs . . . with the engineers discussing characteristics of the subcomponents allowed me to very quickly compare my requirements to the concept design capability. I am interacting with design, engineers, and staff simultaneously. Things become more informal and we quickly get down to business in our trade-off analysis." A Chief Engineer for the Office of the PM said: "It (the VCE) gives us the opportunity to visualize functionality of concepts when reviewing engineering change proposals." Another PM stated, "Yes, seeing the designs and their movements helped speed up the decision making process.

In effect, ACE has become a third-generation VCE system. The use of the desktop, networked, and web-accessed ACE, coupled with use of the CAVE and WorkWall for specific and directed synchronous and asynchronous review activities constitutes a powerful "toolset" for use by collaborative IPTs for simulation-based sustainable product development and acquisition.

The following are listings of applications and advantages obtained to date–based mainly on earlier product development activities and extensive involvement during PMO-sponsored reviews. Most of the evaluations are qualitative and in the form of user satisfaction assessments. They were obtained from interviews with PMs and other functional IPT members who have participated in ACE collaborative activities and were experienced in both VCEs and their functional areas of responsibility. Most of the included statements refer to preliminary stages of the DLC (specification development, concept design, and pre-production activities) since no programs have gone through all

SMART phases using the IPT/ACE integrated process. However, many of these applications and advantages are anticipated for future DLC efforts. Quantitative analyses of cost and schedule savings and benefits are impossible at this time because of the lack of a comparable vehicle and ACE use during a full DLC.

VCE APPLICATIONS

The following is a list of actual and planned ACE functional applications available to individuals and IPTs to support various phases of the simulation-based acquisition process. For completeness several sub-tasks are included for each application.

Requirements/Specification Identification

- Development of concept requirements
- Identification of specifications
- Initial concept and analysis reviews
- Use of M&S and virtual testing to update system requirements

Specification Checking

- Maintenance familiarization–access, size, shape, interference
- Resolution of interferences–(e.g. door opening clearance and human factor considerations)

Design

- Design evaluation of a new concepts (inside and out)–size, shape, specifications
- Evaluation of early design options–major and minor variations, with and without systems and components
- Evaluation of multiple vehicle concepts–tracked vs. wheeled, size and shape differences
- Viewing of vehicles in different environments–field, highway, loading, transport
- Hardware brainstorming–evaluate different design in the same space
- Identify integration issues for various contractors and suppliers

Development

- Review of configuration exceptions–with and without components or attachments
- Comparison with existing system(s)–size, shape, performance

- Support for design tradeoff studies (e.g., vehicle size versus crew size for a future vehicles)
- Group decision support–brainstorming, discussion, consensus development
- Functionality of different concepts and dynamic response to actions
- Evaluation of technology insertion into existing systems (e.g., a wearable multimedia information system for providing soldiers information across various military systems)
- Concept and design reviews for a family of vehicles

Manufacturing

- Layout of plant and manufacturing processes
- Modeling and displays of supply chains

Testing

- Helping to structure specific test events
- Testing evaluation–test design and components to test
- Viewing of dynamic tests–highway, field, obstacle course, loading/unloading, crash tests
- Evaluation of operational environments–tasks that can be performed, loading and transportation, human factors, tasks with functionally designs
- Evaluation of war/battle tactics

Training

- Planning for training–operation, maintenance, and modification
- Conducting training–operation, maintenance, and modification

Maintenance

- Planning for maintenance–access, interferences, size, and shape
- Facilitating the solution of field problems (e.g., tailgate access alternatives for vehicles)

Logistics

- Planning for logistics–system, sub-system, assembly, component quantity, size, shape

Modification

- Planning for removals and replacements

- Displaying a modification activity
- Practicing removals and replacements

Deployment

- Checking for fit–transportation, and storage
- Modeling transportation–land, air, and sea

Termination

- Planning for transportation, salvage, surplus, and storage

Research

- Identification of research needs
- Design of experiments and data collection

VCE ADVANTAGES

IPT immersive and web-based ACE collaborations have uncovered a variety of vehicle issues and supported their problem resolutions during numerous reviews. Example problems encountered include: hard-to-detect integration, interference, safety, and operator-specific human factor deficiencies. ACE has served as a true transformation enabler offering marked improvement over traditional vehicle development methods. Some advantages (and lessons learned) identified as a result of these ACE-supported reviews are:

IPTs

- IPT meetings can be more easily held within and in front of a large VCE rather than around a monitor display (or other first-generation VCE system).
- IPT participates are more able to quickly identify and resolve issues using collaborative, immersive and desktop, interactive web-based environments.
- VCE/IPTs develop consensus sooner and understand better, decisions made because of budget and program constraints.
- Expensive waiting for information and delays are virtually eliminated.
- On-demand access to program status and system design and configuration information provides insights and accelerates upcoming and new actions.
- Efficient and effective connectivity for VCE displays with multiple local and remote system users is unprecedented.

- The number of update status meetings is reduced, permitting more focus on issue resolution and consensus building on system acceptability and utility.

Participants

- Users (soldiers) are empowered to take a direct, active role in fielding a quality system, thereby maximizing their future operational effectiveness.
- Stakeholders do not need to wait for physical hardware to take an active role in development.
- A full-sized (1-to-1) and eye level vehicle display promotes a more natural interaction and correlation to human-scale objects then could be achieved with a monitor display or scale models.
- Subject matter expert (safety, training, test and evaluation, maintenance, transportation, etc.) involvement increases for those who might only have "paper" access to future prototypes and systems.
- Stakeholders can and remain connected with a common "pervasive design visualization" and reusable toolset throughout the DLC.

Organizations

- ACE transcends organizational "serfdoms" (known in the military as "stovepipes").
- System issues are identified and resolved early to cut development timelines and lifecycle costs.
- ACE offers versatile, broad applicability to various phases of the DLC.
- ACE leverages previous government-funded science and technology investments.
- ACE can be used to develop tactics, techniques, and procedures, focus groups, human factors assessments, safety reviews, and testing preparation.

SUMMARY AND CONCLUSIONS

This paper described the evolution and use of VCEs by IPTs with the objectives of: (a) shrinking overall product development life cycles (DLCs), (b) reducing development (and design) costs, and (c) maximizing product utility and value while functioning within cost and budget limitations and operational constraints. Described in the case study were SBA goals and objectives and the initial U.S. Army SMART enabling technology-based and collaborative approach taken to transform future vehicle needs into realities.

The paper has pointed out that public and private sector organizations are constantly seeking better methods for improving productivity and effectiveness in task accomplishment, and that several are using VCE technologies as an enabling technology for IPT activities. Presented was a conceptual model of IPT/VCE interfaces and interactions. Discussed in the context of this model were considerations for integrated and collaborative system and product development that considers the interrelationships between people, work, and technology within the broader context of organizational, social, and technical environments. Also briefly described were several VCE technology systems (the CAVE™, WorkWall™, and an ACE) and the results of literature research and case studies of their use by a public sector technology-based organization.

Also summarized in the paper were the results of an empirical study conducted by the authors that identified the advantages and disadvantages of the CAVE as a VCE. Unique comparison testing (traditional versus VCE) with operational Army user subjects partially validated the advantages of using this immersive VCE for a conceptual design review of a new vehicle system.

A study conclusion reached, based primarily on multiple qualitative responses by the IPT user community, was that VCEs and specifically the ACE offer technology-focused organizations and large IPTs a greatly expanded and improved capability for creating realistic simulated model representations. Importantly, VCEs offer IPTs the potential of reducing months and perhaps years from the DLC–with resultant significant cost savings. These virtual models and their displays have resulted in more efficient and effective IPT collaborative environments when compared to more traditional methods (i.e., 2D drawing and computer monitor images). The feeling of immersion and presence by IPTs within VCEs, clearly contributes to users feeling "involved" in both review and decision processes.

There are several conclusions reached in this research and paper. The first is that technologies exist to allow organizations to enhance their ability to more productively and effectively manage complex product and system DLCs. Several organizations have established functional immersive virtual simulation-based environments and applied them to several *real* programs, involving *real* stakeholder, and *real* challenges and organizational needs. Secondly, the IPT/VCE process has demonstrated the potential for utilizing M&S coupled with VR technology to improve and support the simulation-based acquisition process through collaboration. This capability promotes the assembly of cross-functional teams (in a single and distributed VCE) to identify and resolve potential system problems early in the system development process where the cost of changes is significantly reduced. Importantly, this technology allows multiple individuals to simultaneously view a virtual product or system model while concurrently maintaining communication–both found critical to effective and efficient team decision making and consensus development. Thirdly, this technology supports the U.S. Army's need to significantly improve present acquisition activities and to move into an SBA era. Finally, use of ACE technologies provides a direction for smoothly helping an organization concerned with major product and system development into become a digital enterprise for the future.

Much interest has already been expressed in these vision producing technologies and their applications [reference Ragusa and Bochenek (2001)]. Hopefully this paper will stimulate thought and discussion, causing others to further identify issues and priorities, expand fundamental research, and increase potential and applications. More testing and research are needed, however, to provide insights into other VCE/ACE operational and research issues if these tools and systems are to be integrated into a vision development and broader set of organizational applications for technology management, and to reshape our world for sustainable product development and acquisition–an innovative management of technology initiative for the 21st Century.

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Management of Technology: Key Success Factors
for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

25

EFFECTIVE METHODS FOR NEW PRODUCT DESIGN PROCESS

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INTRODUCTION

It is no secret that we are living in a time of accelerated change. There is extreme pressure to deliver more effective products, more quickly, more reliably and more economically. Fortunately new technologies are continually providing us with options to help us rethink the way we work. In the new product development arena the increased importance of time to market together with the need to contend with global marketing issues have forced to accelerate the design development process and to turn concept into reality in a short time span. (Chakravarthy et al. , 2000)

There are many ways that a product idea becomes a product, and the methods and approaches for performing this translation process vary widely depending on industry sector, product type, and the talents and "style" of the individuals who drive the process. At the top of the value chain, where the consumer directly uses the product, the process of innovation, market stimulation, and definition of requirements is intense, and may dominate the corporate mindset.(IMTI ,2000)

Considering the required time, cost and requirements of the new product design process in today's world, efficiency occurs to be a major concept. Performing high costly new design project may sometimes cause the companies spend more than they will gain and also having a very long design process may even cause the companies loose the opportunities in a fast, rapid changing and competitive market. This occurs to be major issue in durable goods industry. By the globalization and reduction of the barriers between the countries, the efficiency of a new product design process increases its importance day by day.

To be able to achieve high quality products, wide variety and rapid New Product Development (NPD) have been developed with number of alterations in the way enterprises are organized, and in particular in their engineering activities. Therefore the enterprises focus to an increasing extent on their core business and delegate manufacturing and design of parts and major subassemblies to suppliers and subcontractors (Court et al., 1997). The pressure of reducing product development time-scales has led to the traditional sequential design and manufacture process being superseded by a parallel activity in which many specialists perform their tasks. This has been commonly termed concurrent or simultaneous engineering.

However, Court et al. (1997) argue that information is the foundation of the diversified, global marketplace, of concurrent engineering and of continuous improvement. They also point out that today is the traditional design and development of a product more focused upon the incremental improvement of previously established approaches and techniques. NPD entails that different phases of product development are performed, to some degree, parallel, and the coordination of activities and communication between locally and globally dispersed members has to be solved.

Design work within NPD is an important issue, if the design work is to be successful, namely the process of systems engineering/architecture, the task breakdown and the project structuring must be performed. The success of design work depends on the existence of a communication system that provides the right information in the right place at the right time. (Chroneér, D. et al., 1998)

New product design process initially starts with the Concept Generation and Design process. Concept Generation for new products is becoming more and more challenging as the products have to address global customers with contemporary technology and short product life spans.

Next comes the term product design with its narrow sense to refer to the detailed design phase, which constitutes the specification of design parameters, the determination of precedence relations in the assembly, and the detail design of the components, both material and process selection.

There is a range of various design approaches in the literature (Pugh (1990), Ulrich and Eppinger (1995) etc. Many of them describe different activities involved in the design of a product. The following activities, or aspects, of the design process are often considered to be essential. (Chroneér et al., 1998)

- Exploration of the problem
- Generation of alternative solutions
- Evaluation of solutions
- Communication and information among actors

In another classification, Pugh, (1991) defines the term Product Design containing five major phases as Recognition of Need, Definition of the Problem, Gathering of Information, Conceptualization & Evaluation, Communication of Design.

Recognition of Need. Before solving the problem the engineer must identify the needs of the user.

Definition of the Problem. Most engineering problems are not clearly defined at the outset. This requires investigation of the background of the posed problem, collection and analysis of data, economics, causes and effects, and other pertinent information.

Gathering of Information. Information is gathered from many sources such as textbooks and technical journals, trade journals, vendor catalogues, patent gazette, specifications and codes, technical experts, and other sources for information.

Conceptualization. Creativity is an important ingredient to the solution of most engineering problems most of the time good ideas come from many sources, such as textbooks, handbooks, concept books, etc. Therefore, the design engineer must "think up" the idea.

Evaluation. Potential solutions must be compared so that the engineer may decide on the best solution. For evaluation to take place there must be both comparison and decision-making.

Communication of Design. The final solution of the engineering problem results in a product, or the final documents that represent the product. (Pugh, 1991)

Here those terms, covering both concept and detailed design processes, will be explained and discussed, and some techniques will be given to improve the total design process and finally current state and future visions of these functions will be given.

CONCEPT DESIGN

A new product concept can spring from many sources: a customer articulating a specific need, an inventor intuiting that there's a better way to do something, a marketer seeing a gap in the competitive marketplace, or an executive doodling on a napkin over dinner with a client. Regardless of its source, the result is a concept for a product that then must be refined and optimized to arrive at a product solution that correctly balances performance, functionality, cost, and value. Concept development processes define not only the product specifications and the product's basic physical configuration but also the extended product offerings such as life-cycle services and after-sale supplies. (IMTI, 2000)

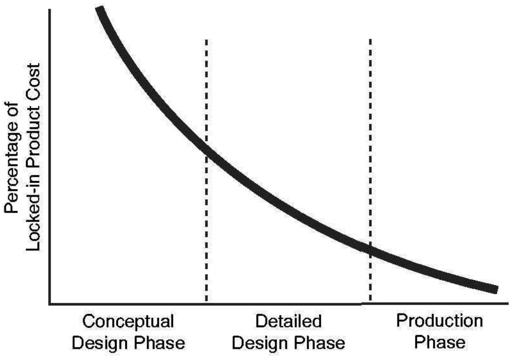

Figure 1. Over 90% of the ultimate cost to manufacture a product is determined in the conceptual design phase of the product life cycle. (IMTI, 2000)

A useful representation of a product is a vector of attributes (e.g., height, weight, price, capacity, etc.). Here the attributes refer to both customer needs (also referred to as customer attributes or customer requirements) and product specifications (also referred to as engineering characteristics or technical performance metrics). Griffin and Hauser (1993) offer a comprehensive discussion of the issues associated with assessing and using customer needs. Given a representation of a product as a set of attributes, conjoint analysis is a structured approach to optimally determine the target values of these attributes. (IMTI, 2000)

Attributes are an abstraction of a product. Concept development also involves the embodiment of these attributes into some kind of technological approach, which is called as the core product concept. The decision of which technological approach to pursue is often supported by two more focused activities: Concept Generation and Concept Selection, which can also be handled by the logical steps, defined below.

The first step in the methodology is to break down the process of concept management into logical steps so that a proper control and protocol can be developed. (Krishnan et al., 1998)

1. **Concept Creation and Generation:** The development and creation of new ideas by using various methods of creativity to come up with a very large number of concepts. Even at this very early stage of concept generation interaction is maintained with the collaborating partners using various creativity techniques like synectics and brainstorming.

2. **Concept focus and evaluation:** Using the design strategy approach for word class management a framework is developed looking at the core values and core competency of the organization. Using this framework the concepts are clustered, grouped and evaluated.

3. **Concept Engineering:** This is the engineering of the ideas, converting the fuzzy concepts into usable consumer oriented ideas .Well noted methodologies of TQM and QFD are used to further narrow down the clusters of concepts to workable two or three clusters.

4. **Concept integration and finalization:** This is the final evaluation and selection of the concept or concept cluster for integration into the integrated product development cycle. This phase draws inputs from the collaborating partners with special evaluation norms and weightings .The needs of customers have a very strong bearing on the concept cluster selected. (Krishnan, V et al., 1998).

DESIGN PROCESS

Design is a critical process for a firm. It capitalizes on a firm's core competencies and determines what new competencies need to be developed. It is also the most obvious driver of change—new products and services often define new markets and require new processes. (Russell, D et. al., 2002)

Product design specifies which materials are to be used, determines dimensions and tolerances, defines the appearance of the product, and sets standards for performance. Design has a tremendous impact on the quality of a product. Poor designs may not meet customer needs, or may be so difficult to make that quality suffers. Costly designs can result in an overpriced product that loses market share. If the design process is too lengthy, a competitor may capture the market by being the first to introduce new products or features. However, rushing to be first to the market can result in design flaws and poor performance, which totally negate any first-mover advantages. Design may be an art, but the design process must be managed effectively.

An effective design process:

- Matches product or service characteristics with customer requirements,
- Ensures that customer requirements are met in the simplest and least costly manner,
- Reduces the time required to design a new product or service, and
- Minimizes the revisions necessary to make a design workable (Russell, D et. al., 2002)

Once the conceptual design of the product is completed, the next step is to drive the design down to the lowest level of detail required to actually make product. This is where over 90% of a product's engineering costs occur, and where innate quality - the product's ability to perform as specified and satisfies the customer - is determined.

Concurrent design practices using collaborative, multi-disciplinary teams (integrated product teams, or IPT s) have gone a long way in making sure the manufacturing side of the house gets a chance to influence the product design early in the process, as well as get a head start on designing the manufacturing execution approach. However, the sophistication (and usage) of computer-based product design lead that of computer-aided process design by a substantial margin. Design optimization for both product and process is still done primarily by a prototype-test-refine procedure.

Modeling tools are used to capture the physical (mechanical and electrical) design, and simulation tools are used to engineer and evaluate specific features but are rarely depended upon to determine final design.

Integrated product/process design is widely regarded as a need, but the enabling tools have not yet evolved to support its realization. Electronic product data exchange is common but often requires human intervention. Many engineering and computing tools exist to facilitate the transition of a product design from the conceptual stage to a final, detailed design. For discrete products (i.e., manufactured parts and assemblies), the product modeling tool (CAD system) that generates the conceptual design is usually the same one used for detailed design. The software tools used for analysis and simulation are usually separate products from the CAD systems, also called as CAE tools and the degree of integration of these tools with CAD systems varies widely. If designs are created in a distributed manner between organizations within or across companies, the use of different CAD systems can severely complicate the integration of CAD models with analysis and simulation tools. Especially the data translation from one system to the other may even cause unsolvable problems. Unfortunately, most of the CAE tools do not have the flexibility and ease of use as CAD tools; therefore a translation process is a must.(IMTI ,2000)

In addition to that, most of the CAE tools contain a set of sub processes, such as preprocessing process which covers the model preparation, mesh or grid generation, solution process, boundary conditions and solution parameters, and post-processing covering graphical and alphanumerical evaluation of the results.

TECHNIQUES FOR IMPROVING THE DESIGN PROCESS

As the need for improvement in the design process has been vital, new techniques and methods are being searched. Considering the design process in a generic product development process, most of the activities are, in common way, thought to be as sequential. In this type of handling, each activity has a pre or a post activity and the sequence of these activities are tight. Whatever the type, characteristic or requirement of the activities, they must be hold until their application time comes. In other words, even a standalone activity, which has no requirement from its predecessors, must hold until a certain time too. A delay in one of the activities absolutely causes a delay for the next ones.

Obtaining the problems and costs due to this kind of handling, a new method, which has the philosophy of simultaneous activities, has been developed for the design process, named Concurrent Design. Since the 1970's, with the invention of so-called *concurrent engineering* and the simultaneous advances in Europe in design theory and design science, a new attitude has started taking root. This new perspective realizes that just because design cannot be quantified to the same degree as engineering analysis does not mean it is irrelevant. Indeed, it is now a generally accepted truth that the decisions made during the design stages of product development can account for more than 80% of a product's total quality and cost. This makes design more than just an important component of product development and engineering; this makes design the cornerstone of engineering

Dean & Unal (1992) define concurrent engineering as "getting the right people together at the right time to identify and resolve design problems. Concurrent engineering is designing for assembly, availability, cost, customer satisfaction, maintainability, manageability, manufacturability, operability, performance, quality, risk, safety, schedule, social acceptability, and all other attributes of the product".

Improving the design process involves completely restructuring the decision-making process. and the participants in that process. The series of walls between functional areas must be broken down and replaced with new alliances and modes of interaction. For that aim, some methods are given blow, which most of them are also components of a Concurrent Design Process. Those methods are:

1. Establishing multifunctional design teams,
2. Making design decisions concurrently rather than sequentially,
3. Designing for manufacture and assembly,
4. Reviewing designs to prevent failures and ensure value,
5. Designing for the environment,
6. Measuring design quality,
7. Using quality function deployment,
8. Designing for robustness, and
9. Engaging in collaborative design.

Here only the Concurrent Design process will be handled, since it is more of interest and main study area of the authors.

CONCURRENT DESIGN

Concurrent design helps improve the quality of early design decisions and thereby reduces the length and cost of the design process. Design decisions overlap; therefore, one stage of design is not completely finished before another stage begins.

Concurrent design also involves incorporating the production process into design decisions. In many cases, design engineers do not have a good understanding of the capabilities or limitations of their company's manufacturing facilities; increased contact with manufacturing can sensitize them to the realities of making a product. Simply consulting manufacturing personnel early in the design process about critical factors or constraints can improve the quality of product design. .(Russell, D et. al., 2002)

One more difference between sequential design and concurrent design is the manner in which prices are set and costs are determined. In the traditional process, the feasibility study includes some estimate of the price to be charged to the customer. However, that selling price is not firmed up until the end of the design process, when all the product costs are accumulated and a profit margin is attached, and it is determined whether the original price estimate and the resulting figure are close. This is a cost-plus approach. If there are discrepancies, the product is sold at the new price, a new feasibility study is made, or the designers go back and try to cut costs. Remember that design decisions are interrelated; the further back in the process you go, the more expensive are the changes. Concurrent design uses a price-minus system. A selling price (that will give some advantage in the marketplace) is determined before design details are developed. Then a target cost of production is set and evaluated at every stage of product and process design. Techniques such as value analysis are used to keep costs in line.(Russell, D et. al., 2002)

The main advantage of the concurrent design comes from the parallel performing of the tasks. Although, the scheduling of those tasks is more complex than ever, some project scheduling techniques, such as PERT/CPM, are being used to coordinate. It should also be noted that in engineering activities, specially numerical analysis or simulation studies where the physical phenomena is transferred to a virtual domain, using the high speed hardware and optimized software, lots of design iterations can be handled in a very short period of time without affecting the status of the other studies. Also proper inter-communication and data transfer form all components of the project, the tasks are mostly evaluated with up to date constraints or boundary conditions. This, of course, reduces the number of redundant studies and increases the chance for the success.

CONCLUSIONS

The Current State of Practice and Current State of Art and the Future Vision of the terms discussed in this article are given in Figure 2. As can be seen from this figure, in the future some business functions will be integrated with the systems that manage product realization so thoroughly that many of today's distinctions will disappear. A new class of tools will support integrated product realization functions such as Concept Definition and Detailed Design at every step of the process, and these tools will operate seamlessly in a plug-and-play environment where no data ever has to be recreated or manually converted to support different applications.

State Map for Integrated Product Realization & Life Cycle Management

Function	Current State of Practice	Current State of Art	Expected 2005 State (Major Goals)	IMTR 2015 Vision (Major Goals)
Concept Definition & Optimization	• Accept and quote to customer requirements • Iterative dialog with customer • Product team examines and evaluates alternatives and selects solutions • No integration of design and requirements data • Little up-front attention to life-cycle issues • Lots of "guesstimating"	• QFD used for voice of the customer • Extensive model-based analysis of alternative concepts (parametric and other) • Automated requirements management tools are emerging • Real-time evaluation of alternatives in limited applications (automated cockpits) • Internet-based requirements reviews using collaborative tools • Customer guides concept design	• Customer requirements automatically translated into physical concepts-default functional design • Collaborative environments supported by knowledge tools and interactive analysis • Emerging capability for automated porting from requirements to design • Connectivity and interoperability of requirements and design data • Customer voice integrated with the design process through access to captured and operational knowledge • Move toward shared assessment of core capabilities • Automatic conversion of regulatory requirements into design concept constraints	• Real-time virtual prototypes, evaluated and optimized • Customer voice integrated with the conceptual evaluation process based on enterprise-wide data • Compatibility of requirements and ultimate product design automatically integrated with extended enterprise resource and business issues • Connectivity and interoperability of product reqiurements and capabilities automated design from requirements • On-line updating and optimizing of conceptual design in a learning envorinment • Concept optimization merges with product design • Integration of regulatory requirements with conceptual design
Detailed Design & Optimization	• Data used for product/process design based on static, sometimes outdated historical info • Huge variability in practice, from "back of envelope" to 3-D CAD • Primarily paper-based design, especially in process design • Build/test/refine prototyping loops • Modeling & simulation tools seldom affect final process design • Computer-aided process planning is not pervasive • IPPD acknowledged as need but not fully realized • Product data exchange common but requires human intervention among disparate systems	• IPPD implemented in collaborative environments • Data used for product/process design based on current, validated information (Chrysler, Levi's) • Scattered use of design advisors and generative process planning • Commercial feature-based planning systems available for specific tools • Process design optimization within factory • Product data exchange (STEP) used by leading companies for product definition • Proprietary architectures used as de facto standards	• IPPD implemented through maturing toolset • Product/process design based on captured knowledge and real data • Limited use of design "cockpits" and shared knowledge bases for Detailed Design and Optimization • Automated decomposition and planning for feature-based process planning • Process design optimization throughout supply chain • Widespread use of product and some process data exchange with disparate systems • Common reference architectures for Detailed Design and Optimization	• Institutionalized IPPD with automated "cockpits" and mature toolset for optimizing product & process design across extended enterprise • Product/process design based on excellent captured knowledge and real-time and forecasted data • Process design optimization and generation of control infromation in real time from requirements definition • Product represented as single object, including all design, process, and related business/resource data • Design standards and information applied to shared products • Real-time planning based on extended enterprise models • Enterprise-wide reference architectures include product & process design

Figure 2. Current State and Future Vision of Concept Definition and Design Processes (IMTI, 2000)

Engineering tools will support a much improved – faster, cheaper capability, and these tools will share information seamlessly. Therefore, integration and configuration of manufacturing systems to produce a new of modified product will be easy and efficient, and use of best-in-class tools will be the norm. From the interface with the customer and the marketing world, to idea and design, to finished product and life cycle support, a continuously enriched stream of information will guide the enterprise through each step of an optimized, systematized, and synchronized product realization process. The path from concept to delivery will be managed to ensure that the right information is available to all who need it, including what is to be done, when it is to be done, why critical decisions have been made, and who is accountable. A rich information set augmented with flexible, on-demand presentation capabilities will support each enterprise function, providing information tailored to the needs of the individual and the task, with full assurance of protection of proprietary information. (IMTI, 2000)

The use of CAD, CAE, CAM, ERP/ERM and other enterprise applications will be positively effective on the design process. Using the developing hardware and software tools, the incredible computation power of the computers will shorten the tasks or activities within a deign process. Also with increasing storage capabilities of computers, the amount of the data handles grows day by day and within this data more abilities can be achieved with the use of proper and effective data handling tools. As an example, at first we were able to model or simulate only a pencil put on a table in a room, but as the development continues, we can next model pencil and the table and later pencil, table and the room altogether. This of course needs a huge computation power but on the other hand accuracy of the simulation or numerical study increases since we put our boundaries to far way form the physical activities.

But at that point, the ease of use of the software and hardware is important. By helping the design engineers be able to use those tools in design process, a very drastically reduction may be obtained in the design periods.

Also, the importance of Concurrent Design methodology has been obtained. Parallel execution of multidisciplinary tasks have positive effect both on time consumed for the design process, effective use of the resources by reducing redundant activities and on the accuracy of the activities since all activities are inter-communicating and all are up to date information level.

Finally, in this study, major steps in New Product Development process have been investigated. As stated, the most important ones are Concept Generation and Detailed Product Design processes. A literature survey has been conducted on these subjects and many different ideas and results from various researchers have been given and discussed. As the conclusion, the current state and future vision of these terms have been stated this in fact has a dynamical characteristic and must always be updated with new developments in these subjects.

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Management of Technology: Key Success Factors for Innovation and Sustainable Development
L. Morel-Guimaraes, T.M. Khalil and Y.A. Hosni (Editors)

THE DYNAMIC ROLE OF INNOVATION DERIVATIVES IN TECHNOLOGICAL INNOVATION

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INTRODUCTION

Technological innovation is a central issue in economics and management, since it is one of the major activities through which firms, industries, and countries create value. While the derivatives of technological innovation, *Technology Push* and *Demand Pull* have been broadly accepted (Mowery and Rosenberg 1979), most of this research has concentrated on supply-side derivatives: the activities and internal capabilities of firms, and their interaction with technological innovation (Dosi 1988). Schmookler (1966), however, has suggested that demand-side derivatives are also important.

Following Schmookler, Mowery and Rosenberg (1979) have emphasized a balanced approach which considers technology push and demand pull as highly interrelated: each is a necessary but not sufficient condition for innovation. In this paper, we use this approach to address the question: How does their interaction between the two sources of technological innovation develop over technology life cycle? *Technology Push* and *Demand Pull* are each considered as the derivative of technological innovation from the supply- and demand-sides, respectively.

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Oligopolistic competition with product differentiation (Anderson et al., 1992) is the basic structure in developing our model. By adopting a multinomial logit model in describing the demand for differentiated products, the equilibrium of technological innovation is derived under the constraints of the market's requirements which stem from the evolution of the demand-side. The equilibrium level of technological innovation, which is represented as the performance of the main attributes, is modeled as a two-stage game in which firms first choose the level of technological innovation and then choose the price of its products. As a result, the unique sub-game perfect Nash equilibrium is derived under the restriction of symmetry. Based on the equilibrium derived, *Technology Push* and *Demand Pull* are modeled to describe the derivatives of technological innovation as well as the interaction between them.

MODEL

Following Lancaster (1971), consumers perceive the quality of a product through its main attributes. Therefore, the quality perception of a consumer (q_i) can be described as follows,

$$q_i = x_i^{\eta}, \text{ where } 0 < \eta \leq 1 \tag{1}$$

where x_i is the performance level of product's main attribute representing the level of technological innovation of the firm producing the product, and η is the extent of technology saturation in the market where $\eta \in (0,1)$. Therefore, η represents the degrees of decrease in the marginal utility a consumer gains from quality improvement and the evolution of PLC (Product Life Cycle) when it goes to zero. We followed the assumption of Adner (2002) that consumers gain a decreasing marginal utility from improvement of a product's main attribute. Therefore, we can denote consumers' maximum willingness-to-pay for the product *i* as follows,

$$w_i = \alpha \cdot q_i = \alpha \cdot x_i^{\eta} \tag{2}$$

where α is consumers' marginal willingness-to-pay for a unit of improvement in product quality.

Following Anderson et al. (1992), each individual is supposed to have a deterministic utility function U_i defined on C_n, where C_n is a finite choice set of differentiated products. For each $i = 1,\ldots,n$, the utility derived from alternative i can be written as $U_i = V_i + \varepsilon_i$. Here, V_i is called a consumer's conditional indirect utility from purchasing product i and reflects the preferences of the subpopulation for the ith alternative, while ε_i is a random variable with zero mean taking into account the idiosyncratic taste differences of members of a subpopulation (Anderson et al., 1992). Products $i = 1,\ldots,n$ are the variants of a differentiated product sold at real prices $p_1,\ldots,p_n$. We assume that a consumer's conditional indirect utility is given by the additive form,

$$V_i = w_i - \beta \cdot p_i = \alpha \cdot x_i^{\eta} - \beta \cdot p_i, \qquad \text{where } i = 1,\ldots,n, \tag{3}$$

If we assume that all the disturbances ε_{in} are independently identically distributed with Extreme-Value distribution, then the multinomial logit demand function can be derived as follows,

$$s_i(\underline{p};\underline{q}) = \frac{\exp(\alpha \cdot q_i - \beta \cdot p_i)}{\sum_i^n \exp(\alpha \cdot q_i - \beta \cdot p_i)}, \quad j = 1,\ldots,n. \tag{4}$$

with $\underline{q} = (q_1 \cdots q_n)$ and $\underline{p} = (p_1 \cdots p_n)$. By equation (4) describing a probabilistic demand function, we can derive the demand for product i, D_i, as follows,

$$D_i(\underline{p};\underline{q}) = M \cdot s_i(\underline{p};\underline{q}) = M \frac{\exp(\alpha \cdot q_i - \beta \cdot p_i)}{\sum_i^n \exp(\alpha \cdot q_i - \beta \cdot p_i)}, \qquad j = 1,\ldots,n. \tag{5}$$

where M denotes the total demand for the products in the markets.

Let us assume that each firm produces only one product and is the sole producer of that product, so the index $i=1$ through n denotes a specific firm producing a specific product. Firm i's production costs comprise a sunk cost K, which is constant and equal for all firms, and a technology dependent marginal cost $c_i(q_i)$. The n firms are players of a non-cooperative game. Suppose also that firms set prices and the product attribute's level of performance representing the firm's technological innovation. The firm supplies consumers with the quantities demanded at the price set. In other words, firm *i*'s strategy is comprised of the price it charges and the performance of its product's main attributes. Then firm *i*'s (expected) profit can be defined as

$$\pi_i(\underline{p};\underline{q}) = [p_i - c(q_i)] \cdot D_i(\underline{p};\underline{q}) - K \tag{6}$$

where the D_i is the demand for product *i* of equation (5).

Now suppose that the marginal cost is constant with respect to quantity. But technological innovation increases marginal costs according to a strictly convex curve. Hence, we can define the marginal cost function as follows,

$$c(q_i) \equiv c(x_i) = x_i^{\delta}, \quad \text{where } \delta > 0 \tag{7}$$

Here we can define a firm's *innovation capability* as $\pi = 1/\delta$ where the capability of a firm's innovation, specifically process innovation, increases with the increase of π resulting in lower production costs with the same level of technological innovation.

THE NASH EQUILIBRIUM OF TECHNOLOGICAL INNOVATION

A Subgame Perfect Nash Equilibrium of Prices

If we consider the second stage of the game where firm *I* has chosen quality q_i while all other firms have selected q. Then there is unique price equilibrium for the game given by,

$$p_i^* = c(q_i) + \tfrac{1}{\beta} \cdot \left[1 - \left\{\exp(\alpha \cdot q_i - \beta \cdot p_i^*)\right\} / \Delta\right] \text{ and} \tag{8}$$

$$p_j^* = c(q) + \tfrac{1}{\beta} \cdot \left[1 - \left\{\exp(\alpha \cdot q - \beta \cdot p_i^*)\right\} / \Delta\right] \quad j = 1,\ldots,n \text{ and } j \neq i \tag{9}$$

where

$$\begin{aligned}\Delta &\equiv \exp(\alpha \cdot q_i - \beta \cdot p_i^*) + \textstyle\sum_{\substack{j=1 \\ j \neq i}}^{n} \exp(\alpha \cdot q - \beta \cdot p_j^*) \\ &= \exp(\alpha \cdot q_i - \beta \cdot p_i^*) + (n-1) \cdot \exp(\alpha \cdot q - \beta \cdot p^*)\end{aligned} \tag{10}$$

The Nash Equilibrium of Technological Innovation

The payoff function for the first-stage game from the evaluation of firm i's profit at the equilibrium is given

$$\tilde{\pi}_i = \frac{M}{\beta \cdot (n-1)} \Phi - K \tag{11}$$

where $\Phi \equiv \exp\{\alpha \cdot (q_i - q) - \beta \cdot (p_i^* - p^*)\}$. By the first-order condition with respect to x_i, we can derive the Nash equilibrium of Technological Innovation as follows,

$$x_i^* = \left\{ \frac{\beta}{\alpha \cdot \pi \cdot \eta} \right\}^{\frac{1}{\pi \cdot (\eta - 1)}} \tag{12}$$

where x_i^* represents product I's degrees of innovation compared to those of other products. Therefore, we can interpret and define x_i^* as Δx_i^*. In addition, if we define Δs as *the stage of PLC*, $1 - \eta$, we can transform the equation (12) as follows,

$$\Delta x_i^* \equiv \left\{ \frac{\beta}{\alpha \cdot \pi \cdot (1 - \Delta s)} \right\}^{\frac{1}{\pi \cdot (1 - \Delta s)}} \tag{13}$$

where, as Δs goes to 1, the market evolves into the stage of maturation in PLC where the degrees of technology saturation increase. Figure 1 below shows the required level of technological innovation from the interaction between demand-side decreases and the evolution of PLC.

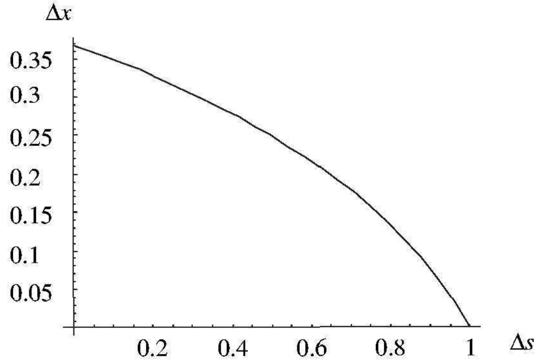

Figure 1. The Equilibrium Levels of Technological Innovation with the Evolution of PLC.

THE ROLE OF *TECHNOLOGY PUSH* AND *DEMAND PULL* IN TECHNOLOGICAL INNOVATION

Technological Innovation by *Technological Push*

We assume a *duopolistic market structure* with only two firms producing two types of products. Each product's quality is determined by the level of its main attribute. Therefore, each firm's marginal costs vary according to the level of the main attribute of its specific product, the marginal price of the products [?], $\beta_1 = \beta_2$, and the decrease in the consumer's marginal utility (DMU), $\eta_1 = \eta_2$. We define an *Entrant* and an *Incumbent* as follows: the performance level of the main attribute of firm 2 (*Entrant*)'s product is superior to that of firm 1 (*Incumbent*)'s, $x_2^* > x_1^*$. Then, we can define the payoff function of the *Entrant* for the first-stage game as,

$$\tilde{\pi}_2 = \frac{M}{\beta}\Phi - K \text{ where, } \Phi = \exp\{\alpha \cdot (x_2^\eta - x_1^\eta) - \beta \cdot (p_2^* - p_1^*)\} \tag{14}$$

The *Entrant* has incentive to innovate, if $\tilde{\pi}_2 > 0$ as follows,

$$\frac{M}{\beta}\Phi - K > 0, \tag{15}$$

Let us define this incentive to innovation for the *Entrant* as *Technology Push (TP)*. Thence we have the following condition,

$$TP \equiv x_2^{\eta} - x_1^{\eta} \geq \tau + \varpi \text{ where } \tau = \frac{\beta}{\alpha}\cdot(p_2^* - p_1^*) \text{ and } \varpi = \frac{1}{\alpha}\ln\left\{\frac{\beta\cdot K}{M}\right\}. \tag{16}$$

Then, the TP decreases with the evolution of PLC, that is when $\Delta s \to 1$ as in Figure 2 below.

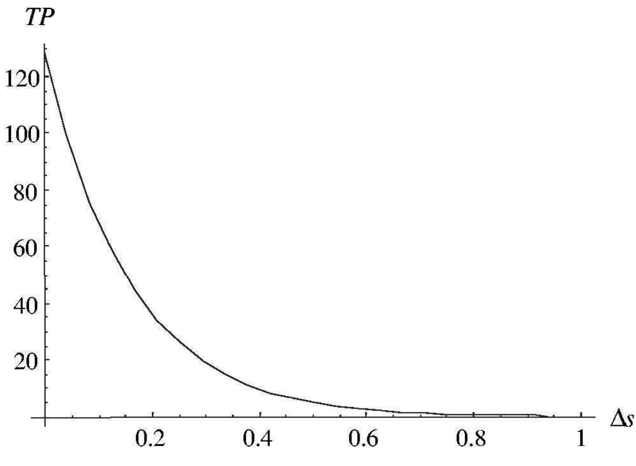

Figure 2. The Decrease of Technological Push with the Evolution of PLC.

Technological Innovation by *Demand Pull*

As in the case of *Technological Push,* we assume a *duopolistic market structure* with only two firms producing two types of products each with different levels of the main attribute defining its product's quality. Each firm's marginal costs are different depending on the levels of the main attribute of its specific product, the marginal price of the products are equal, $\beta_1 = \beta_2$ and the DMU, $\eta_1 = \eta_2$. As above, define an *Entrant* and a *Incumbent* as follows: the performance level of the main attribute of firm 2 (*Entrant*)'s product is superior to that of firm 1 (*Incumbent*)'s, $x_2^* > x_1^*$. Let us define consumer surplus as follow,

$$\begin{aligned} cs_i &= \alpha \cdot q_i^* - p_i^* \\ &= \alpha \cdot x_i^{*\eta} - p_i^* \end{aligned} \tag{17}$$

Then, the *Entrant* has more incentive to innovate from the demand-side when $cs_2 > cs_1$, which is defined as *Demand Pull* (DP): $\alpha \cdot x_2^\eta - p_2^* > \alpha \cdot x_1^\eta - p_1^*$. Therefore the *DP* satisfies the following condition,

$$DP \equiv x_2^\eta - x_1^\eta > \xi \text{ where } \xi = \frac{1}{\alpha} \cdot (p_2^* - p_1^*) \tag{18}$$

Then, the DP decreases with the evolution of PLC, that is when $\Delta s \to 1$ as in Figure 3 below.

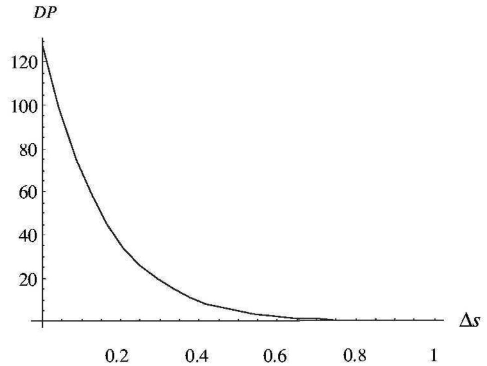

Figure 3. The decrease of *DP* with the evolution of PLC.

THE INTERACTION BETWEEN *TECHNOLOGY PUSH* AND *DEMAND PULL*

If we define the difference between *Technology Push* (TP) and *Demand Pull* (DP) as follows, Γ

$$\Gamma \equiv TP - DP = \tau \cdot (\frac{1-\beta}{\beta}), \quad \text{where } \tau = \beta \cdot \xi \text{ and } \beta > 0, \tag{19}$$

we can derive the following relationship between *Technology Push* and *Demand Pull* as in Figure 4. The increasing rate of TP's share in the derivative of technological innovation is greater than the increasing rate of DP's, following the change in marginal price (β). In other words, the role of the supply-side in technological innovation increases rapidly as consumers become indifferent to price changes, while the role of the demand-side increases incrementally as consumers become sensitive to price changes.

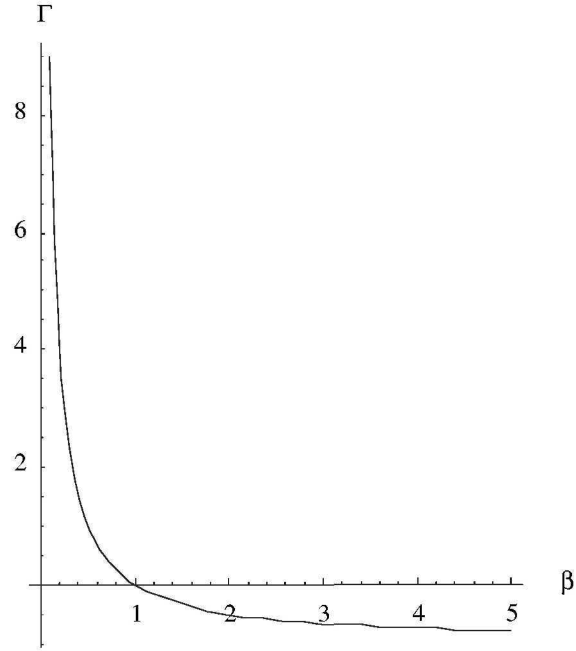

Figure 4. The Dynamics of the Relative Difference between Technology Push and Demand Pull over the Product Life Cycle

THE INTERACTION BETWEEN *TECHNOLOGY PUSH* AND *DEMAND PULL* IN THE GLOBAL DRAM MARKET

Let Memory Density (Mbit) represent the main attribute reflecting the technological innovation of DRAM. From the results of the estimation of Multinomial Logit Model for the world DRAM market[10], we can derive the relationship between *TP* and *DP* in the case of DRAM innovation. Figure 5 below shows the derived results for the 16M DRAM generations. However, we have found similar results for the previous generations, 16K, 256K, 1M, 4M. Figure 5 shows the distinctive feature of the DRAM market, in which *Technology Push* is the major derivative of its technological innovation, as expected.

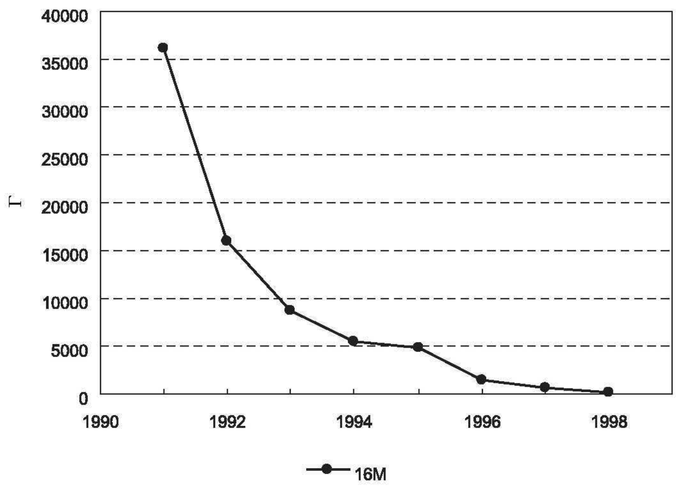

Figure 5. The Relationship between *TP* and *DP* for 16M DRAM

[10] Please contact authors for the specific estimation method and results.

CONCLUSION

Under the equilibrium of technological innovation derived from the interaction between technological innovation and the demand-side, we modeled and analyzed *Technology Push* and *Demand Pull* as the two principal derivatives of innovation. We have maintained the balanced approach which considers *Technology Push* and *Demand Pull* as highly interrelated. Each is a necessary condition for innovation.

Under the assumption of a duopolistic market structure with only two firms producing two types of products, each with different levels of the main attribute which constitutes the product's quality, we derived the subgame perfect Nash equilibrium of technological innovation. As a result, we can conclude that both *Technology Push* and *Demand Pull* decrease with the evolution of the product life cycle (PLC).

As consumers become sensitive to price change, the major derivative of technological innovation is described by more complex patterns. Therefore, the marginal prices of products are one of the major factors determining the principal derivative of technological innovation between *Technology Push* and *Demand Pull.*

Governments have carried out *Technology Push* policy primarily in the form of R&D investment. But, because its role and impact on technological innovation has been little studied and ill-understood, the importance of *Demand Pull* has not been fully recognized in government policy making.

We recommend that governments complement *Technology Push* policy with *Demand Pull* policy which promotes the commercialization of technological innovations. This would increase the efficiency of both. Based on the results derived here, we suggest some policy tips for decision makers.

> First, the improper regulation of industries or industry structures which do not consider the demand-side interaction of technological innovation can lead to "lock-in" in technological innovation which works against the promotion of social welfare. Second, good government policy should reflect the differences of industries or firms at different stages of technological innovations. Finally, governments should include the commercialization of the outcomes of technological innovation in poilcy making to promote the integrated efficiency of technology policies.

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27

A MODEL FOR THE STUDY OF CLUSTERS: NEW MEDIA FIRMS IN VANCOUVER

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INTRODUCTION

According to a variety of classical and modern texts there are good reasons for firms to "cluster" in regions (Jacobs and de Jong 1992; Maggioni 2002; Raines 2002). These reasons range from purely economic (opportunities for the purchase of specialized inputs, including knowledgeable workers), to the less tangible "social capital" benefits of co-location (Putnam 1993; Fountain 1998; Nahapiet and Ghoshal 1998). Economists, economic geographers, policy analysts, and regional development scholars and agencies have studied the reasons for and benefits of proximity for firms (Mytelka and Farinelli 2000; Bresnahan, Gambardella et al. 2002).

In the present paper we briefly review some of the most recent literature on the topic and then provide a case study of clustering among firms in the multimedia industry in Vancouver, Canada. Vancouver is the largest city in the west coast province of British Columbia (BC), with approximately 2 million residents in the Greater Vancouver Regional District.

At first blush, it might seem that firms would want to locate themselves apart from their competitors. As anyone who has walked through a garment district, or diamond district, or driven through the industrial valleys of Europe, this is clearly not the case. Even if we remove the firms that are clustered in order to have access to raw materials – say, in a wine district, or near a source of power or natural resources – the effect is pronounced and historically valid.

The Silicon Valley, located south of San Francisco on the west coast of the United States, is the obvious example that people point to for an example of a successful cluster of firms, but others abound, ranging from the "Route 128" computers and biotechnology cluster near Boston to the light manufacturing, textiles, and other small firms clustered in Italy's Emilia-Romagna region. Successes such as these are attractive, not just to consulting firms and the writers of airport business books, but to regional governments who would like to replicate that success in their own region. Regional governments also appreciate the fact that the policy "strings," in this area at least, are not held by the national government.

Canada has been significantly influenced by thinking about clusters for more than a decade, dating back to the commissioning of a "diamond" study of Canada's economy in the early 1990s and then the more recent work coming out of the Cluster Mapping Project at Harvard (Porter 1991; Porter 1998). The 1991 study was a duplicate of earlier work by Michael Porter on national competitiveness in a variety of developed countries, which didn't include Canada. Carried out under Michael Porter's supervision, the 1991 study identified local or regional cooperation as a factor in the subsequent international competitiveness of nations. Subsequent national government policy in Canada has put forward several measures designed to improve competitiveness, including policies that promote economic clusters. One of those measures has been support for research, and one outcome has been a flourishing of work by Canadian researchers on national systems of innovation, with a focus on clusters as a factor in those systems.

As a large, regionally diverse country, the "clusters" work in Canada contrasted with much of the European research, which was based on smaller, national systems. As a result, interest grew, and funding became available, for a series of regionally focused studies of the clustering process. The present paper reports on one of those studies, funded by Canada's Social Sciences and Humanities Research Council (SSHRC) as part of its 'Initiatives for the New Economy" program. The Innovation Systems Research Network, as it came to be known, includes sub-national, regional networks of researchers from all parts of Canada, organized themselves into clusters of proximate teams of researchers (see http://www.utoronto.edu/isrn/). The present author is part of one of those sub-regional networks, known as "InnoCom" (see http://www.sfu.ca/innocom/). Innocom is located in Vancouver Canada, and is hosted by the Centre for Policy Research on Science and Technology (CPROST), a unit of Simon Fraser University. Innocom has teams of researchers looking at clusters in the multimedia, biotechnology, wireless, wood, and food services industries.

DEFINING THE MULTIMEDIA INDUSTRY

Multi-media is one of those industries that is difficult to define. Sometimes also referred to as "new media," multimedia is a term that made more sense a few years ago, when it was easy to see the difference between new forms of media and the "traditional" forms of books, movies, television, radio, and newspapers. While those forms still exist, they have all been strongly affected by the computer and communication revolutions and no longer are they reasonably understood as businesses apart from new media. There is scarcely a newspaper in business that does not also have a web site, or a television network without a "streaming media" counterpart, or a book publisher that does not also produce CD-ROM versions of some of its book list. This process of merging media forms is sometimes called "convergence" and has been extensively studied elsewhere(Olson 1988; Gilder 1993; Castells 2001).

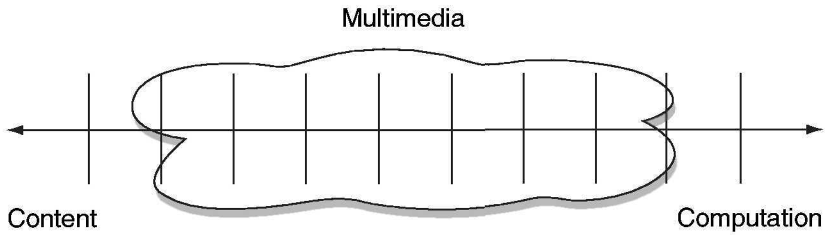
In our region the government has also grappled with this issue. BCStats, in conjunction with the Ministry of Competition, Science and Enterprise, has examined the broader issues of how to define the ``high technology sector" in BC. This work was done as part of an ongoing project that attempts to quantify the industry. They issue an annual report, the latest of which is Profile of The British Columbia High Technology Sector 2002 Edition. This report attempted to map North American Industry Classification System (NAICS) codes to multimedia job categories and found that many job functions within multimedia are not described by these codes or do not fall within a single area of coding. Multimedia work can be a product and/or service as companies look both towards content and computing.

For the purposes of this study, we sought to avoid the problem of "multimedia is everything," but also wanted to have something of a definition that wasn't simply a list of "approved" technologies or media forms. It seemed to us that the key feature that distinguishes a multimedia firm from one that is merely using multimedia technologies as part of its business is the extent to which the firm can be said to be innovating in *both* of the two originating or defining aspects of multimedia, namely "content" and "computation." Without both of those things you do not have the potential for multimedia.

One interviewee maintained that there is not a multimedia industry, per se, but a group of traditional media companies integrating new technologies into their existing business models. This raised the question of multimedia being a new business model, rather than a traditional product or service. Despite this unorthodox view of multimedia, the interviewee supported our working definition of multimedia: "firms located in the space between content and computation."

To better understand this definition, it may help to think of a continuum that extends from a "pure" content firm (such as a script writer), to a pure "computation" firm (such as a designer of microelectronics). These extremes of the multimedia spectrum would be outside our area of interest, even though microelectronics, for example, are used in the creation of multimedia products. The challenge, however, is finding firms that do make a realistic contribution in both areas and are not merely using pre-formed content or pre-existing computation (hardware or software) solutions. As we found in our study, it is necessary to have a fairly relaxed attitude to what constitutes a "contribution" in order to have a sufficient number of firms to study.

Figure 1. Multimedia defined by a continuum



This definition helps put a bit of a boundary on a traditionally "fuzzy" industry. It also reinforces the notion that there is a value chain in the industry – some people are doing some aspects, some people are doing others (Porter 1985). As we shall see, below, this notion of a value chain is not deeply embedded in the members of the multimedia cluster in Vancouver.

The Vancouver Public Library, which created a directory of "new media" firms in 2001, used a definition of multimedia that is similar to ours but has greater emphasis on communication:

"...not so much an industry as a set of applications, software, skills and techniques that are adaptable to a variety of fields. The underlying theme is communications: digital, interactive, wireless, convergent, networked, mobile business and personal communications" (New Media Directory 2001).

Several industry players that we interviewed expressed concern about the perception of multimedia as a cultural industry and not an economic industry. "It should be seen as an industry which needs investment rather than support, which is a common way government usually views a cultural industry" (Interviewee). According to these respondents, money needs to be invested in every facet of the multimedia industry. Examples include building large staging areas for post-production work and sponsoring multimedia work that is created for reasons other than satisfying government "Canadian Content" rules and incentive programs.

As one interviewee put it, "we can't expect a kid with a grant to produce a cultural CD-ROM product about the fur trade in Canada to turn around and launch a multimedia company." The change in this funding structure for an evolving industry is dependent on the definition of multimedia changing from a cultural industry to an industrial sector. Multimedia is emerging as an industrial sector with dynamic products and services and innovative practices, which are in some cases unique to BC.

MULTIMEDIA CATEGORIES

Multimedia firms, even with the above definition, still fall into some diverse categories. For example, educational multimedia is not the same as computer games, and computer games are not the same as animation, even though there are "bridge" aspects between these categories (the "edutainment" category is an obvious one, as well as the extensive use of animation within computer games). For the most part we have tried to be as inclusive as possible with the various categories of multimedia, while acknowledging the special characteristics, drivers, business realities, and styles of the different players.

Categories are important for this type of a study, however, as they are the way in which the various firms within the cluster self-organize and form industry associations, special interest groups, and social networks. These convergence points are a key element in the vitality, strength, and viability of a cluster of firms and for this reason they are important points of inquiry as well as useful “levers” for policy intervention.

Categories are present within the Vancouver multimedia industry to such an extent that there is good reason to wonder if the industry as a whole can be considered a cluster. As an example, there is a very active Association of British Columbia Animators. There is also the (much larger) New Media Association of BC (see http://www.newmediabc.com). When a recent tax change came about that improved the situation for the animators, it was the smaller, more focused association that was interviewed in the newspapers, not the larger, over-arching one. Similarly, in interviews with the various industry players, most had connections to a small number of local peer companies and to international customers but relatively few connections to local multimedia firms that were not in their category.

The main categories of new media in Vancouver are education and educational technologies, computer games (represented by the multinational giant of the industry, Electronic Arts (see http://www.ea.com), animation, a few specialized software companies such as SchemaSoft (developers of scalable vector graphics format, or SVG, software), and an assortment of web and Internet related firms.

SOME CHARACTERISTICS OF THE INDUSTRY

To put multimedia in the BC context, it is important to note the trends and changes in the BC economy as a whole. Like many other regions of Canada, the traditional base of the BC economy is moving away from a resource-based economy and toward knowledge-based industries. Statistics Canada research indicates that in 1993, other goods overtook resource industries in terms of employment. "We are communities of people that can be “resourceful,” not only “resource-based” (Premier's Technology Council, Second Quarterly Report).

Figures 2 and 3: Technology Industry in B.C.

Figure 2

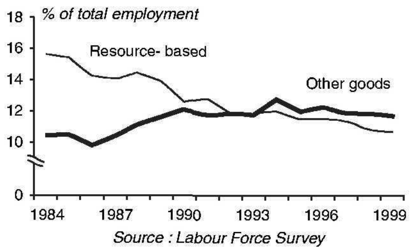
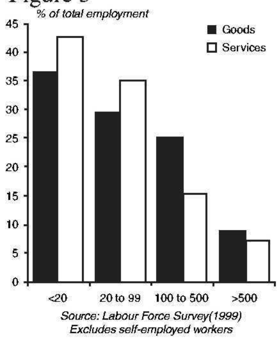


Figure 3



Like many Canadian provinces, the BC economy is largely made up of smaller firms. A majority of employment occurs in smaller firms of less than 100 people, as indicated in Figure 2. According to a survey of Canadian Multimedia Industry organizations in 2000, 51% of multimedia organizations have fewer than two employees. Approximately 13% of multimedia activity in Canada occurs in British Columbia (see further statistics at http://strategis.ic.gc.ca/SSG/it05390e.html).

According to BC Stats, the gross domestic product generated by high technology firms in BC was $3.7 billion in 2000. Since 1992, the GDP growth of high tech industry in BC has outpaced other industries and has had a profound impact on the economic fabric of BC, but the growth of high technology GDP was below high technology growth nationally. The government of BC has acknowledged this lag and established the "Premier's Technology Council," co-chaired by Mr. Paul Lee, Sr. Vice President & Worldwide Studios Chief Operating Officer of Electronic Arts, Inc. In its First Quarterly Report in November 22, 2001, the council noted that: "When asked to identify the industrial sector that will contribute the most to [BC citizens'] future economic prosperity, more British Columbians chose high technology than any other sector (Ipsos-Reid-B.C.TIA poll)."

The trade benefits are the obvious rationale for an export-oriented industry like multimedia. One interviewee stated (after the unfavourable decision for BC in the soft wood lumber dispute with the USA): "Post-production and film is the best pipeline to [..export revenues...] without giving up a single rock or tree."

The growth of the multimedia industry has been very strong in the past decade. According to BCStats data, "High tech GDP has grown every year since 1985" and high tech sector employment rose at over three times the rate of employment in other industries. Companies such as GVFX Vancouver have grown from 5 people in 1998 to 25 people in 2002. A comparison of some of the characteristics of multimedia across Canada and in BC is given in Table 1:

Table 1 Multimedia Characteristics, BC and Canada

	BC (Source: 1998 BC New Media Industry Survey)	*Canada (Source: Industry Canada 1999 Profile of the Multimedia Industry)*
% of 1-10 Employees	40	63
% of more than 30 Employee	30	8
Ownership – private	67	91
Ownership - publicly traded	23	5
Education - University Degree	70	62
Education - College Degree/ Technical School	26	30
Education - High School	4	7.5
Financing – Personal	32	65
Financing - Venture Capital	27	15
Financing – IPO	9	3
Financing – help from Govt within next 12 mos.	41	25

IS THIS A CLUSTER?

The industry statistics for the region seem to indicate the ingredients for an industrial cluster in the multimedia sector. There are a reasonably large number of firms and they are growing. There is policy awareness of the sector and regulatory (tax and other) initiatives to promote firms in the industry. Finally, the industry itself has sufficient self-organization to have created several networking events and associations. There is more to a cluster than just the outward appearance, however. There is also the reality of whether firms actually work together or are they simply neighbours?

According to generally accepted definitions of an industrial cluster, in order for the multimedia industry in Vancouver to qualify as a cluster it would have to have the "commonalities and complementarities" that Porter speaks of (Porter 1998). When we started the research we more or less assumed that we were studying a cluster. As we met more and more firms, however, the assumption began to falter. In particular, we noticed relatively few "complementarities." This led us to try to measure the extent to which our local collection of multimedia firms could be called a cluster and why. The challenge lay in creating an operational definition for "what is a cluster?"

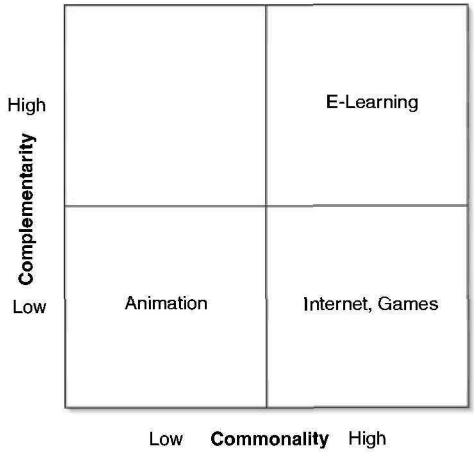
Making an operational definition of commonalities and complementarities for our research process proved relatively straightforward. For commonalities we looked for common membership in industry associations, common "root" firms or investors in the genealogy of firms (Smith 2002), and attendance at industry-specific social and networking functions. Complementarities were defined according to the "value chain" model of local inter-firm connections, using the horizontal and vertical linkages described by Mytelka and Farinelli (Mytelka and Farinelli 2000) and Porter's own "value chain" model (Porter 1985).

At this point the measures we have are preliminary only. Further refinement of the concept is required, as well as a more rigorous data collection and scoring mechanism. That said, we do have some indications coming from our interviews of the viability of our cluster. In addition, by crossing the two variables, we may be able to look at four different types of cluster.

Commonalities were assessed, in this preliminary formulation, according to a simple "high/low" descriptive variable, with firms being measured relative to their common features relative to the industry group as a whole. Complementarities were measured similarly, with firms being measured as having low complementarities if they reported few local value chain linkages and high if they reported several local linkages. These firm-level measures were later aggregated for the sub-industry groupings that make up the cluster as a whole, although, again, these results should be considered very preliminary at this point.

We turned these two aspects of clustering into a two-dimensional grid, with commonalities on the vertical axis and complementarities on the horizontal axis. Figure 4 illustrates this process.

Figure 4: Commonalities and Complementarities as Cluster Metrics



The location of the various sub-sectors in the figure, above, are subject to revision as we learn more about the use of this method of understanding clusters. For now, it is illustrative, at best. That said, anecdotal evidence from the case studies provide some background for why we might place firms in one quadrant or the other.

The animation sub-group within the multimedia cluster scores low on the "commonality" measure in large part because there are relatively few firms engaged in this business in Vancouver. As a result, they are more or less unique in their approach and business practices and technology. They score low on the complementarity axis because they are relatively unconnected to each other, albeit well connected to the global marketplace and supply of animation talent. The exception to this is the moderate connections that they have to local schools and design programs.

The Internet (web design, streaming media) and electronic games firms are relatively more numerous and more homogenous in their approach, technology, and customer profile. They are extremely well connected to each other in industry associations and networking events, and they have deep connections into the local higher education scene. They do not have a pronounced "value chain" orientation, however, and therefore also score relatively low on the complementarity axis. The one exception to this is Electronic Arts, which is sufficiently large that it has begun purchasing specialized services from related firms such as sound studios. This may be a prelude to a more integrated local cluster.

The e-learning group is comprised of a diverse set of firms with a high degree of commonality as evidenced by their common roots (many spin-offs from local university research groups or related firms), their extensive networking activities (there is a special interest group on e-learning within the New Media BC association, for example), and their collective initiatives in the areas of marketing and promotion. At the same time, the industry is more vertically linked than some of the other sub-groups, with specialized firms taking up roles in service of other local firms, and some firms contracting with others to fill in gaps in their technology, market, and business practices.

CONCLUDING REMARKS

In practical terms, the benefit from having a measure like this is that we can orient our research efforts to shift our attention away from cluster description efforts and towards identification of obstacles to cluster formation. Research can also begin on comparing these patterns or "scores" across a time-series, looking for connections to contextual variables such as maturity of the industry, relative size of the component firms, absence or presence of related policies and regulations, and so on.

Similarly, from a policy perspective, policy makers can balance their efforts between initiatives that are designed to enhance and take advantage of existing clusters and those efforts that are more appropriate for the creation of clusters.

We will continue working with these measures in the coming months and hope to compare them across clusters in the same city and between clusters in different cities. For now, we will be focusing on refining the metrics and enhancing the operational definitions so that we have a more robust measure.

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28

AN APPROACH TO EVALUATE THE QUALITY OF A PRODUCT WHEN MULTIPLE QUALITY CHARACTERISTICS ARE CONSIDERED

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INTRODUCTION

One of the most critical issues encountered in the area of quality engineering is the selection of a proper quality loss function to relate a key quality characteristic of a product to its quality performance. The loss function can be used to evaluate quality loss in term of monetary units. The loss function enables managers to quantify unobservable costs. Therefore, it aids manufacturers to evaluate more rigorously quality improvement projects. However, using inappropriate loss functions will lead to inaccurate results that give either underestimate or overestimate of the expected quality costs (Drain and Gough, 1996; Spiring and Yueng, 1998). Moreover, these traditional univariate loss functions (such as step loss function and Taguchi loss function) are not informative approaches to evaluate the quality of a product when multiple quality characteristics are present and interact with each other.

Most of the studies of quality system or product quality assessment deal with a single quality characteristic to determine the quality loss. From the customer's point of view, however, products are often judged by more than one quality characteristic. For this reason, a multivariate quality evaluation model is required to capture the overall costs/losses caused by bad quality, when multiple quality characteristics are present. In this paper, a numerical example is given showing the use of inappropriate univariate loss functions would underestimate quality loss or even ignore the loss incurred because of the poor quality.

COST OF QUALITY: UNIVARIATE APPROACH

Most classical studies have considered the step loss function as a quality measurement system (Sullivan, 1984; Evans and Lindsay, 1999). This approach assumes that costs do not depend on the actual value of the quality characteristic with no cost if product within the specification, and a fixed cost, C_r, called rejection cost, when product out of specification. This function, for a single quality characteristic, can be written as:

$$L_R(y) = \begin{cases} 0 & LSL \leq y \leq USL \\ C_r & otherwise \end{cases} \tag{1}$$

Although this step loss function has been widely used, Taguchi (1984) used empirical evidence to show that the step loss function does not effectively reflect a customer perception of quality. He stated that for a quality characteristic, a customer-identified target value is the only value that completely satisfies the customer. Any deviation from the target value would cause customer dissatisfaction and result in an economic loss. Dr. Taguchi declared that *quality loss is defined as the loss a product costs society for the time the product is released from shipment* (Taguchi et al., 1989). His approach can evaluate the quality loss for items within the specification limits.

Taguchi (1984) indicated that quality loss should be measured in monetary units. He characterises this loss or cost as a quadratic function. This loss reduces to zero when the quality characteristic is exactly on the target value, otherwise the loss increases quadradically away from the intended target value. If y is the actual value of the quality characteristic, Taguchi defines the loss per unit, $L_Q(y)$, for the products that have been shipped to customers as:

$$L_Q(y) = k(y-T)^2 \tag{2}$$

where T is the target value of the quality characteristic. Define k as C_r / Δ^2, where Δ is the tolerance of the specification limits and C_r is the rejection cost per unit. The loss $L_Q(y)$ estimates the cost to the society from the failure of the product to meet its target value for a given quality characteristic. The loss can be incurred by customers as maintenance or repair costs; by manufacturers as warranty cost; or by the society, in general, as pollution or environmental costs. He also stated that for a quality characteristic, the customer-identified target value is the only value that completely satisfies the customer. This simple quadratic loss function has been accepted and widely applied in many situations (see for examples: Phadke, 1989; Taguchi, 1986; Taguchi et al., 1989).

By considering both the rejection cost and quality loss, the quality level of a product can be estimated by the sum of these values. Hence, the quality cost per unit produced can be expressed as:

$$L(y) = L_R(y) + L_Q(y) \tag{3}$$

The expected quality cost, $E[L(y)]$, (internal and external failure costs) per unit produced can be obtained by adding the integral of the Taguchi loss function to the values of the specification limits and the integral of the step loss function outside the values of the specification limits, i.e.:

$$E[L(y)] = k\int_{LSL}^{USL}(y-T)^2 f(y)dy + \int_{USL}^{\infty} C_r f(y)dy + \int_{-\infty}^{LSL} C_r f(y)dy \tag{4}$$

where $f(y)$ is the probability density function of y.

If there are more than one quality characteristics present and they are independent, then Eq. (4) can be written as:

$$E[L(y_i)] = \sum_{i=1}^{n} \{k_i \int_{LSL_i}^{USL_i} (y_i - T_i)^2 f(y_i) dy_i + C_{ri}[1 - \int_{LSL_i}^{USL_i} f(y_i) dy_i]\}, \text{ for all } i \quad (5)$$

The information obtained from Eq. (4) and Eq. (5) can be used for the economic design of $\bar{x}$ control charts (Elsayed and Chen, 1994), in which the expected quality cost is used in order to find the most economic control limits and parameters for the control charts, hence minimising the overall costs. The economic design of engineering process control (EPC) also uses the information of off-target (Taguchi's approach), in order to seek an optimal control policy that will minimise the overall costs (Wang and Yue, 2001). As the review of literature shows, most researchers have focused their work on a single quality characteristic, whereas products are often judged by more than one quality characteristic. Therefore, to avoid mistakes in decision-making, a multivariate quality evaluation cost model is required as an extension of the step loss and Taguchi loss functions to capture the overall cost caused by bad quality, when multiple quality characteristics are present.

COST OF QUALITY: MULTIVARIATE APPROACH

In this section, a mathematical model will be presented which allows the calculation of the loss functions when the key quality characteristics of the product are more than one.

Rejection Cost

Consider n N-type quality characteristics, $\mathbf{y} = (y_1, y_2, ..., y_n)^T$, the rejection can be defined as $C_r(y_1, y_2, ..., y_n) = 0$ when $LSL_i \le y_i \le USL_i$ for all i $(i = 1,2,...,n)$. This is based on the concept of single step loss function, that is, there is no quality loss when the product performance falls within the specification region. Considering two quality characteristics shown in Figure 1, the rejection region I and II represent the ones where a product characteristic fails to meet one of the specification limits and both of the specification limits, respectively. It is reasonable to assume that the rejection cost for product characteristic falls within region I is lower than that of region II. It should be observed that the number of types of rejection region is equal to the number of quality characteristics. For example, if there are three quality characteristics of interest, three different rejection regions I, II and III are realised. As simply seen, there are 3^n regions for n N-type quality characteristics, which include the specification region and all the rejection regions. As a result, the maximum numbers of rejection regions is $3^n - 1$. The expected rejection cost associated with region I can be shown as $C_r^I \cdot P(R_I)$, where C_r^I and $P(R_I)$ represent the unit rejection cost associated with region I and the probability that the product falls within region I, respectively. Similarly, the expected rejection cost associated with region II can be written as $C_r^{II} \cdot P(R_{II})$. As a result, the expected total rejection cost becomes:

$$E[L_R(y_1, y_2,...y_n)] = \sum_{i=1}^{n} C_r^i \cdot P(R_i) \tag{6}$$

where i represents the types of rejection region for $i = I, II,...n$

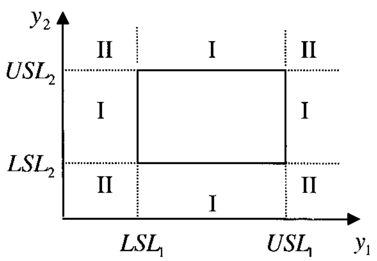

Figure 1. Rejected Regions for Two Quality Characteristics

Multivariate Loss Function

Let n quality characteristics and their associated customer-identified targets be donated by $\mathbf{y} = (y_1, y_2,..., y_n)^T$ and $\boldsymbol{\mu} = (\mu_1, \mu_2,..., \mu_n)^T$, respectively. A multivariate quality loss function is required as an extension of the Taguchi loss function to capture the overall losses caused by bad quality, when multiple quality characteristics are present, which can be expressed as (see Chen and Kapur, 1989):

$$L_Q(y) = \begin{cases} \sum_{i=1}^{n} \sum_{j=1}^{i} k_{ij}(y_i - \mu_i)(y_j - \mu_j) & LSL_i \le y_i \le USL_i \\ 0 & elsewhere \end{cases} \tag{7}$$

When the specification region of interest is implemented, the expected quality loss where n quality characteristics are present can be expressed as:

$$E[L_Q(y_1, y_2, \ldots y_n)] = \int_{LSL_n}^{USL_n} \int_{LSL_{n-1}}^{USL_{n-1}} \cdots \int_{LSL_1}^{USL_1} L_Q(y_1, y_2, \ldots, y_n) \cdot f(y_1, y_2, \ldots, y_n) dy_1 dy_2 \ldots dy_n \quad (8)$$

Other types of multivariate loss functions can be used to assess the quality of the product rather than the multivariate Taguchi loss function as mentioned above. If there is enough historical data (rejection cost vs. quality characteristics) then a multivariate polynomial loss function can be formulated by using regression method. In this case, the quality loss is measured as a function of the quality characteristics, i.e.

$$L_P(y) = \begin{cases} f(\mathbf{y}) & LSL_i \le y_i \le USL_i \\ 0 & elsewhere \end{cases} \quad (9)$$

where $\mathbf{y} = (y_1, y_2, \ldots, y_n)^T$ are the quality characteristics.

It is noted that the multivariate Taguchi loss function is a special case of the multivariate polynomial loss function. The advantage of the multivariate polynomial loss function is that it provides better estimation of the quality loss of the product, however, this technique requires a large amount of historical data before it can be applied, which is time consuming.

THE EXPECTED TOTAL COST

We assume that the expected total quality cost is the sum of the expected rejection cost and the expected quality loss. Consider where two quality characteristics are present, the expected quality cost per unit produced can be written as:

$$E[L(y_1,y_2)] = C_r^I[\int_{-\infty}^{LSL_2}\int_{LSL_1}^{USL_1} f(y_1,y_2)dy_1dy_2 + \int_{LSL_2}^{USL_2}\int_{-\infty}^{LSL_1} f(y_1,y_2)dy_1dy_2 + \int_{USL_2}^{\infty}\int_{LSL_1}^{USL_1} f(y_1,y_2)dy_1dy_2$$
$$+ \int_{LSL_2}^{USL_2}\int_{USL_1}^{\infty} f(y_1,y_2)dy_1dy_2] + C_r^{II}[\int_{-\infty}^{LSL_2}\int_{-\infty}^{LSL_1} f(y_1,y_2)dy_1dy_2 + \int_{USL_2}^{\infty}\int_{-\infty}^{LSL_1} f(y_1,y_2)dy_1dy_2$$
$$+ \int_{USL_2}^{\infty}\int_{USL_1}^{\infty} f(y_1,y_2)dy_1dy_2 + \int_{-\infty}^{LSL_2}\int_{USL_1}^{\infty} f(y_1,y_2)dy_1dy_2] + \int_{LSL_2}^{USL_2}\int_{LSL_1}^{USL_1} L_Q(y_1,y_2)f(y_1,y_2)dy_1dy_2 \quad (10)$$

where $L_Q = k_{11}(y_1-\mu_1)^2 + k_{12}(y_1-\mu_1)(y_2-\mu_2) + k_{22}(y_2-\mu_2)^2$ and $f(y_1,y_2)$ is a joint probability density function for y_1 and y_2.

NUMERICAL EXAMPLE

The proposed quality evaluation cost model can be used to identify and measure costs associated with product quality. The information provided by this model can be used as a means for measuring financial benefits associated with quality improvements. Managers can make use of this model as a decision-making tool to decide whether to invest or not to invest in a particular quality improvement project, or how much they need to invest for the quality improvement project. Therefore, selecting an accurate quality evaluation cost model to evaluate the product or process quality is an important decision, since it can affect the quality related decision-making.

In this section, a numerical example is illustrated showing that using only single quality characteristic, as a key performance indicator is not appropriate to reflect the actual quality loss incurred by bad quality when the product performance depends on more than one quality characteristic.

Consider that there are two quality characteristics of interest, y_1 and y_2, which are statistically independent, and they are assumed to follow a bivariate normal distribution with $\sigma_1 = 0.8$ and $\sigma_2 = 1.5$. The specification region limits are given by $8 \le y_1 \le 12$ and $17 \le y_2 \le 23$ respectively, in which the internal failure costs (rejection costs) are \$30 for product quality characteristic(s) that falls into region I and \$50 for that of region II. The customer-identified target values are $T_1 = 10$ and $T_2 = 20$. The process means for y_1 and y_2 are 11 and 21, respectively. Further, it is assumed that the quality loss coefficients k_{11}, k_{12}, and k_{22} are 5, 2 and 2 respectively. Table 1 summarises the expected total quality cost for different approaches.

Table 1 Expected quality cost for different approaches

	Univariate ($)	Multivariate ($)
Step loss function		1.089
y_1	0.683	
y_2	0.394	
Taguchi loss function		10.215
y_1	5.298	
y_2	3.302	
Total	9.677	11.304

If the company only uses either one of the quality characteristics as the key quality performance for measuring the quality loss then the expected quality loss, when using the step loss function Eq. (1), would be $0.683 and $0.394 for y_1 and y_2 respectively. Further, if Eq. (2) were used for quality loss measurement then the quality loss for y_1 would be $5.298 and y_2 would be $3.302. By using the multivariate expected cost function Eq. (10), the expected total quality cost is $11.304. The loss function and its contour are shown in Figure 2 and 3, respectively. For this particular example, the multivariate expected total quality cost of $11.304 is greater when compared with the sum of rejection cost and quality loss for each single quality characteristic ($9.677 = $5.981+$3.696). It is found that by using the univariate approach to measure quality characteristics, there is a probability to underestimate the expected quality loss. For this particular example, an underestimation as high as 14.39% would be realised by using an inappropriate cost model to evaluate the quality level of the product. However, if the value of k_{12} is negative then the expected quality loss will be less than the sum of quality losses for single quality characteristic. In this case, the company will overestimate the expected quality loss of the product.

The main factor contributing to different results for these two approaches is that the multivariate loss function has considered the customers perception of the quality characteristics are interdependent, leading to a cost (k_{12}) which accounted with the reactions of customers regarding to the product quality based on multi-characteristics, whereas, the univariate approach only judges quality characteristics individually. It is shown that, from this particular example, the univariate approach always leads to inaccurate results (underestimates the expected total cost per unit produced), and hence ignoring the costs for quality improvement projects that in terms of appraisal and prevention costs. Note that the difference between these two approaches is directly proportional to the value of k_{12}, i.e., the cost reflecting the interdependence of external costs.

CONCLUSION

In this paper, a multivariate quality evaluation cost model is presented for evaluating the expected total quality cost per unit incurred for products with multi-characteristics. The quality loss function can be used to evaluate quality loss of products in terms of monetary units; this quality loss includes long term losses related to costs of warranties, excess inventory, customer dissatisfaction, and eventually loss of market share. By identifying this loss, the manufacturers can use this information to evaluate more systematically quality improvement projects. The information obtained from the proposed models can be used for different research areas, such as determining process adjustment control policy and deciding the optimum economic production lot size. However, using inappropriate loss function will lead to inaccurate results that give either underestimate or overestimate of the expected quality loss, hence, affecting the quality related decision-making. It is shown that the proposed quality evaluation multivariate model is a more informative approach to calculate the quality level of a multi-characteristics product. The illustrative examples clearly demonstrate the potential advantages of the proposed approach. For further research, an efficient numerical solution for the model that includes the covariance between the quality characteristics will be sought.

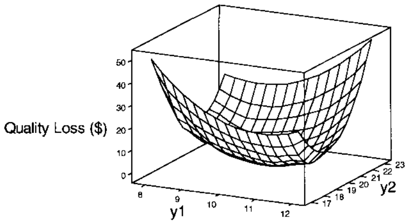

Figure 2 Multivariate Loss Function

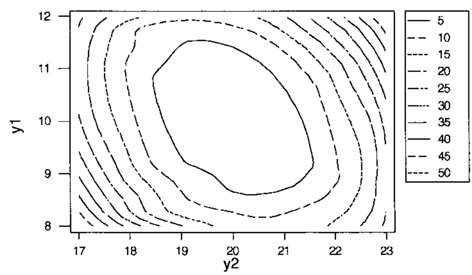

Figure 3 Contour Plot for the Multivariate Loss Function

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