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Contents

The Impact of Computer-Aided Drafting on Design Office Management

T.G. Schilling

ABSTRACT

The impact of higher productivity from CAD equipment within the design office is reviewed. The new responsibilities of the Project Architect, Production Manager, CAD Operator, System Manager, Bookkeeper, and Director of Marketing are outlined. The author emphasizes training over equipment as the key to modernizing design practice. Development of an office data base is highlighted. The paper concludes with a summary of benefits derived from the use of data processing equipment for the management of design information.

1. Introduction

In the construction design field, a new data processing environment is emerging as a result of the increased use of Computer Aided Drafting (CAD), personal and business computers, word processing, and computer time sharing. As more documents are assembled in this environment, issues emerge which challenge the form of design service and how it is carried out.

It is a mistake to think of CAD affecting only drafting. In order to successfully integrate CAD into a professional design office, all job descriptions will have to be reevaluated. The entire office - not just the drafting staff - should realize that in the period ahead their roles will be modified and their work will be performed in fundamentally different ways. CAD will impact every aspect of your practice.

2. Personnel

Cost justifications that rely on a 3 times or greater increase in productivity are fundamentally correct. However, these justifications do not take into consideration the entire management of a design office. In order to make the lease payments on computer equipment, an office with a CAD system must: secure more work; win more design contracts; and perform the work faster. Several new requirements are derived from this increased productivity which will modify the responsibilities of the design professionals involved.

In the time currently spent on one project, an office with CAD is going to perform 3 times as much work. In the same period of time, there will be 3 times as many drawings to check, 3 times as many instructions to give to staff, and 3 times as much work to coordinate with consultants, clients, and reviewing agencies. You are going to be making decisions 3 times as fast.

This pace will impact both the form and content of the Project Architect's job. In order to keep up with a project, the Architect will no longer have time to personally perform some of the drafting. The increased pace of work is a new mental environment; adjusting to it is a mental challenge.

The need for project planning and control is more acute with CAD than with traditional drafting. During the accelerated design and production drawing phases, the cost to the client is increased. Clients are alert to this and need to be reassured that the pace can be successfully managed. Consequently, the reporting responsibilities of the Project Architect will be expanded. More time will be required communicating with operators, consultants, and the client. It is not as convenient to run off a set of check prints when the documents are stored in a computer. Communication will require a greater quantity and variety of intermediate documents such as partial drawings, quick plots, and extractions from drawings. The Project Architect will have a new focus on control and communication.

Between the Project Architect and the CAD operator is the Production Manager. The PRODUCTION MANAGER has responsibility for:

a) Scheduling project work;
b) Production of project documents;
c) Quality control of project documents; and
d) Operator staffing.

With the introduction of CAD, the essential responsibilities of Production Managers are unchanged. However, they will have to learn to supervise new drafting techniques and adjust to the new pace. Rather than managing drafters working with paper, pens, and pencils on drafting boards, the Production Manager will be in charge of operators, working 3 times as fast with computer terminals, and pen or electrostatic plotters. The Production Manager will have some new pressures to deal with.

This is an entirely new working environment for the Production Manager and will require reorientation along with some retraining. Unlike the Project Architect and drafter, the form and content of the Production Manager's job will not be significantly altered. For example, it will not be necessary for the Production Manager to master the high speed CAD input techniques used by the operators. However, he will have the new responsibility of coordinating computer plotted drawings with different drawing technologies used on the same project, including traditional hand drafting, and overlay drafting.

The Production Manager will also be responsible for the staff of operators between periods of peak work load. The cost of time on a CAD system makes it dangerous to stretch out the drafting work on a project. CAD operators will not be able to simply embellish the current drawings until the next project comes on line. The Production Manager will have the responsibility for scheduling and directing work during these periods.

The period between peak work loads is ideal for progress on an office data base resident on the computer. It is an essential element in the data processing resources of the office. Currently, the lasting result of our creative efforts are buildings or structures. If successfully developed, the data base can represent the cumulative knowledge of the design office. An OFFICE DATA BASE would include:

Symbol libraries, standard room templates, drawing checklists, schedules, standard report forms, specification files, drawing notation files, detail libraries, construction cost files, building code checklists, etc.

Work on the office data base should be viewed as development of an information resource for all projects. It is important enough to deserve a job number and a project manager.

Since 3 times as much work will be passing over the desk of the Production Manager in a shorter period of time, expect to pay more salary for this position.

Even more than the role of the Project Architect and Production Manager, the role of the drafter will be completely transformed. The job of a CAD operator is not the same as the job of a drafter. Prior to the introduction of CAD, a drafter was an apprentice to the Project Architect. He or she learned a variety of professional skills while performing drafting work. The CAD operator, on the other hand, must spend a considerable amount of time learning new computer techniques. The techniques for recording design information in a data processing medium are complex. Rather than translating sketches into hand drafted drawings, the operator will have to translate sketches into electronic documents on a computer. The Project Architect may never have to learn these techniques.

By working directly with the Project Architect over a set of drawings, drafters learned aspects of the design profession other than drafting. The Project Architect may no longer have the opportunity to tutor the operator in either the basic aspects or the subtleties of professional practice. In a computer environment, giving instructions and reviewing the progress of work is very different.

As a computer document, the organization of the content of the drawing into levels, symbols, groups, pen numbers, etc. will not be under the control of the Project Architect. Instead, this new responsibility will be largely in the hands of the CAD operator.

The CAD OPERATOR has responsibility for:

a) Input of design information at the computer terminal;
b) Organization of design information on the CAD document; and
c) Accuracy of the final drawing.

Performing these functions at 3 times the speed of ordinary drafting requires a high level of coordination and concentration.

The instructions from the Project Architect will have to be more precise and complete. He will not have the opportunity to look over the drafter's shoulder and correct the work as it is being drawn. The original drawings will now be stored on the system. So, the copies in the flat file will not represent the progress of the day. The drawings on the Project Architect's desk will be out-of-date very quickly. Also, it is not as convenient for operators, while working on a system, to stop and clear up uncertainties in the drawings. Your red lined drawings will have to be more thorough and clear.

It is unrealistic to assume that operators will work a full day directly on the system. This overlooks the requirement for preparation of upcoming work and review of prior work. Work can be performed directly on a CAD system 3 or more times faster than with traditional drafting. However, it takes just as long to check a drawing. A guideline for operators is to spend a maximum of 60% of the day directly inputing project drawings. The balance of the time is spent in communication, inspection, and preparation. The amount of non-system time will vary depending on the nature of the project, the quality of instructions, and the skill of the operator.

Some amount of operator time should include experimentation with new techniques for input of drawing and design information. The purpose of this experimentation is to develop higher levels of efficiency for organization of drawing content and input. It should be encouraged.

At a higher rate of productivity than traditional drafting, and with the increased responsibility for drawing organization, CAD operators are essentially more skillful than drafters. They are worth more money. If they do not realize this when you install a CAD system, they soon will.

Unlike flat drawing files, CAD systems do not take care of themselves. Another key staff position is the system manager. The SYSTEM MANAGER has responsibility for:

a) Overall operating integrity of the system;
b) Installing upgrades or improvements to the hardware and software;
c) Control of files and symbol libraries resident on the system; and
d) Operator training.

Like the railroad engineer with the oil can, the System Manager keeps the system running. Depending on the capability of the individual, the System Manager can develop some of the additional software needed to increase the efficiency of the system for your office procedures and types of projects.

The System Manager is very often a new staff position within a design firm. It may be necessary to recruit this individual from outside of the design profession. They may have a computer science or data processing background. A design office does not have the resources to train a System Manager in data processing skills. He or she must be expected to bring this capability to the job. The System Manager is responsible for the requirements of the system first and may only come to learn some of the requirements of a design profession while on the job.

There are two final roles worth highlighting - the BOOKKEEPER and the Director of Marketing. Without new emphasis on these positions, the investment in new equipment and training will not get under way at all or will collapse. The bookkeeper and Director of Marketing will also have new demands placed on their capabilities.

For equipment, design offices have traditionally had to invest only a modest amount of capital per employee. The funding and maintenance of capital equipment is a new problem. It represents a fixed cost: that is, a cost that will not vary as the work load goes up and down. The equipment leasing company will require you to predict several years ahead the income stream for the office.

The billing cycle will have to keep pace with the increased productivity. The lease payments and maintenance expense for CAD equipment require that fees for service be paid in a business like manner; in other words, less than 60 days. A billing, job cost, and reporting system that operates smoothly is essential. Regardless of industry, an automated accounting system is a logical first step in a phased development program for computer use.

Finally, the DIRECTOR OF MARKETING, whether this is a full time position or a role shared by the office principals, will have to generate more design work. For the first time, this may require the use of modern marketing techniques including: positioning the company in the marketplace; forecasting by market segment; and, product development of new services. Integrating new services into traditional marketing plans will take special emphasis. These new capabilities may have to be acquired by training outside of the design office.

3. Summary

In any business, the essential element for the successful use of data processing is training. This represents the largest expense both at start-up and as CAD impacts design office procedures other than drafting. Training is also the most difficult cost item to quantify. Even more than the equipment, training - or retraining in the case of professionals in practice - is the key to increased productivity. Recommendations for specific programs of training are beyond the scope of this paper.

Once staff has been retrained to work at higher levels of productivity with data processing equipment, they are more valuable. They will be more difficult to replace. Their new capabilities represent a significant investment in modernization, both to the individual design office and to the design profession as a whole. There is a shortage of qualified people with both professional and computer skills. Competition among employers for people with these skills already exists and will probably continue into the foreseeable future. At the outset of training, an employment agreement is worth considering for the well-being of all parties.

Inspite of sales hyperbole and testimonials by professionals already working with CAD, assume that it will require one full year of retraining and overtime in order to master production drafting on a CAD system. This does not mean you will be unable to carry out productive work during this period. You can expect to be able to generate drawings within a matter of weeks with most CAD systems. Assume, however, that it will take a year before you can carry out a complete project on budget and on time without having to train or learn at every step in the process.

On the positive side, firms that have mastered the use of CAD find they can tell clients, "We can produce work as fast as you can review the drawings."

4. Benefits

It is unrealistic to expect a significant improvement over established and well understood production techniques, such as hand drafting, without: changes in the form and content of professional service jobs; and reorganization of design office management. Performing the work of three or more drafters with a single operator and CAD station is a major accomplishment. In most cases, however, this increase in productivity is offset by the cost of owning and operating the equipment.

The major payback for the expense of equipment and training will not come from simply imitating drafting with a computer. In the future, a new form of design service with data processing equipment will be based upon the comprehensive management of design information.

In the short term, the payback for the expense of equipment and training will come from:

a) the increased quality of the documents;
b) the speed with which they are completed; and
c) the increased number of design alternatives that can be generated.

Clients will not only pay for these benefits, some are requesting CAD capability before selecting a design office.

By organizing design services around the management of design information, the content of design documents can be improved. By increasing the content of documents that can be processed by computer, the documents become more valuable. If you can process more of the drawing with a computer, you can record more accurately and you can extract more from the final document.

Computer processable documents are of value to both the design office and the end user. The design office benefits by delivering enhanced or new services such as:

a) Automatic coordination between drawings and specifications, details, notes, and schedules;
b) Automatic extractions from drawings including bills of material, furniture and equipment inventories, etc.;
c) Design decision tracking and reporting; and
d) Facilities management services.

Finally, the client or end user will benefit from the improved quality of service in the form of:

a) With more alternatives, development of design concepts will be more complete;
b) Improved recording of design program information and design decisions; and
c) More coordination between project planning, design, analysis, construction, and operation.

References

The author has derived the observations and conclusions in this paper from his professional background and experience including:

* 11 years in practice as a licensed architect;
* Use of CAD for architectural design and production drawings;
* 3 years with the founding and operation of DESIGN LOGIC, a CAD and data processing service bureau for design professions in the San Francisco Bay Area; and
* One year in software product development for architects with CALCOMP, a CAD manufacturer.

Design Considerations of the OMRAN System; a CAD-System for Construction Engineering in Micro-computer Environment

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ABSTRACT

OMRAN is a turnkey CAD-system for reinforced concrete construction design. It is conceived to fit the micro-computer environment and to support with a high degree of automation the design process for ordinary reinforced concrete multistory buildings. The man-machine interface is very friendly and heavily based on interactive graphic dialogue. The output of the system is a complete set of final and detailed site drawings, notes and computation results.

1. Introduction

Structural engineering was one of the pioneer engineering fields in using computers for aiding the design process. Programs were written as early as the 50's for solving special structural problems, and the need for extensive computations in many design cases led to the use of computers increasingly. Hundreds of computer programs were developed since then to solve a variety of design problems, and this trend was a main research theme for the last 20 years.

However, most of these programs, although extremely useful, cannot be classified as real CAD-systems in today's terminology. They aimed in their majority at finding solutions to difficult design problems rather than enhancing the productivity and the creativity of the designer in general, or automating the design process. Very little attention was paid to man machine interface, and the output of the program was essentially composed of tables of figures and less frequently of design curves. The use of graphics was very limited.

Even in the rare cases when some of these programs could be considered as being real CAD-systems, they were implemented on expensive hardware which prevented their wide-spread application and consequently limited their use.

The present research work aims at developing quite different types of CAD-systems in structural engineering characterized by wide-spread, efficiency and low cost. The main concerns of this approach are:

- every-day design problems,
- high automation level,
- low cost hardware,

The outcome of this research is the CAD-system called **OMRAN** which was conceived for supporting the design process of reinforced concrete multistory buildings.

The field of application of the system might seem relatively limited and specific, but the design considerations and the approach used in developing the system are in fact quite general and could be applied in other fields to develop similar CAD-systems.

In this paper, attention will be focused mainly on the general design considerations to be applied in this type of CAD-system and on the impact of these considerations on the choice of hardware and on software characteristics. These considerations are based upon and derived from a brief analysis of the factors that make a CAD-system successful. The general description of **OMRAN** system is presented with special emphasis on the man-machine interface and the documentation provided by the system as an output of the design process.

2. Factors influencing the success of a CAD system

The success of a CAD-system depends upon a number of factors the most important of which are in our opinion:

- The efficiency of the system.
- The frequency of use.
- The simplicity of use.
- The cost.

The efficiency of the system can be represented in some sens by the degree of automation it provides for the design process. In fact, CAD-systems are designed to aid the design engineer in some or all phases of the design process, and to enhance his creativity. This is normally achieved through an interactive dialogue between the user and the machine. The user supplies the system with the necessary design information, specifications and design directives, while the system should provide him with total or partial results in different forms including production documentation such as drawings, notes,...etc.

It is evident that the higher the degree of automation the CAD-system could provide, the more the user is relieved from the burden of mundane work, and consequently, the more he is able to concertrate on design issues, thereby enhancing his creativity. CAD-systems with poor automation level are not very useful since their efficiency in supporting and aiding the design process is limited.

The frequency of use seems to be an important factor in making a CAD-system successful. After KRAUSE and VESSILAKOPOULOS (1), the design of CAD-systems can only be economical if a high frequent use of the CAD-software is guaranteed. We do agree of course that the economical aspects are not the only motivations behind developing CAD-systems . Other motivations might lead to less frequently used systems, such as the need for extensive computation or simulation, but this type of CAD-system is quite particular and limited . The frequency of use remains a primary issue for the success of ordinary CAD-systems.

The simplicity of use is a crucial factor in the success of CAD-systems like most other software packages. In particular, those CAD-systems designed for wide-spread purposes are generally used by engineers who might have a slight knowledge of computing and computer technology. The training required to use such systems should be as simple as possible , and should need neither deep knowledge of computers nor parallel training in computer technology.

The man-machine interface should be natural. WARMAN (2) considers that increasing the naturalness of the user interface represents a major field of research in the 80's . He argues that more effort should be spent on investigating how designers design in order to improve the naturalness.

The point raised here by WARMAN is very important since simplicity of use and naturalness do not only mean simplicity of the interaction proceedure, but also mean the simplicity of understanding correctly this interaction without any ambiguity to the user and in a manner close to his working habits.

The cost of most CAD-systems is still high. This is due in the majority of cases to the cost of hardware which includes expensive graphic devices. But since common CAD-systems aim at enhancing productivity in order to reduce overall design cost , real wide-spread use of CAD-systems cannot be realized without reducing the cost of the hardware. The prices of graphic devices tend to decrease substantially due to technological advances in this field, but we believe that the most important element for reducing the cost of CAD-systems would be the use of the new generation of micro-computers which provide at the same time excellent graphic capabilities, similar to those of a medium range graphic terminal, and substantial computing power which covers in most cases computational requirements for CAD-systems. The micro-computing environment fits very well the requirements of wide-spread turnkey CAD systems.

3. The OMRAN system

OMRAN Is a turnkey CAD-system for reinforced concrete construction design. It is conceived to fit the micro-computer environment and to support with a high degree of automation the design process for ordinary reinforced concrete multi-story buildings. The man-machine interface is very freindly and heavily based on interactive graphic dialogue. The output of the system is a complete set of final and detailed site drawings, notes and computation results.

4. Basic design considerations

The basic design considerations taken into account in choosing the main features of the OMRAN system were explicitly stated in the objectives of the present research work which was formulated to be "The design and implementation of a low cost and efficient CAD-system for rienforced concrete construction design which can be widely spread and used simply and frequently by experienced or novice engineers through an interactive natural dialogue.".

Each one of these considerations, i.e. low cost, efficiency, wide-spread use, simplicity and frequency of use and naturalness of the man-machine interface, represents, as we have seen in paragraph 2, a factor of success of CAD-systems. Let us examine now in some detail the impact of these considerstions on hardware choice and software characteristics.

4.1. The impact on hardware choice

Three of the above considerations influence directly the choice of the hardware:

- The inteactive natural interface requires intensive use of graphic interaction between the user and the system. This implies graphic display capabilities; i.e.,graphic terminal or equivalent device.

- The efficiency means maximum automation in producing output documentation, i.e. drawings, detailed site plans, notes ,...etc. This implies the use of a graphic plotter.

- Low cost is a major issue for the choice of hardware. The most direct way for reducing the cost of the hardware is to minimize the number of hardware elements required. This was done by:
  * Replacing the graphic terminal by a 16 bit micro-computer with advanced graphic capabilities .The micro-computer is supposed to play here a dual role ,the role of a graphic terminal as well as the role of the central computer. Since the price of the micro-computer is comparable to that of a graphic terminal, a substantial reduction of hardware cost is realized .

  * Using a low cost plotter to perform at the same time plotting as well as printing. A pre-analysis of the functions to be performed by the OMRAN system showed the infrequent need for printing. When required printing can be done by the plotter without real overhead.

The hardware was finally composed of only two units:
- A micro-computer with high resolution graphics.
- A low cost plotter.

The micro-computer wich has been selected for the first implementation of OMRAN is the VICTOR 9000 (SIRIUS 1) with the following features:
- 16 bit 8088 CPU.
- High resolution graphics; 800 X 400 pixels.
- 256 KB main memory.
- 2 X 600 KB floppy disk.

Another feature which favoured the selection of this particular micro-computer is its special graphics capabilities such as windows, variable size characters, RAM character generation, graphic cursor, vertical printing and a powerful graphics package. However, future plans include implementing the system on other micros like IBM PC and LISA.

The plotter used is the HP 7470 . This plotter is equipped with two pens and characterized also by high resolution. It uses ordinary one sheet paper format, but continuous computer paper could also be used to produce large size drawings.

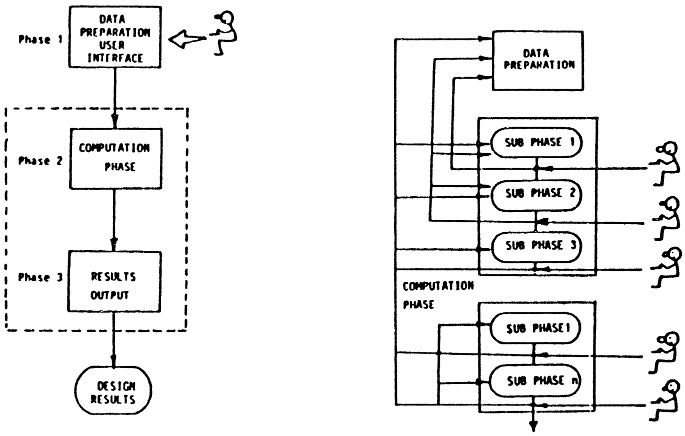
The cost of the above configuration is about 7000 US$ including basic software and the necessary graphics package . This cost is very convenient for our purposes and very competitive for wide-spread turnkey systems.

4.2. The impact on software character

4.2.1. Automation level

An essential objective in designing the OMRAN system was to obtain an efficient CAD-system characterized by a high degree of automation. Thus, it is important to define precisely what we mean by high automation level. But before doing that, let us examine the case of a fully automated CAD-process. The different design phases in this type of system are shown in figure [1-a]. The interaction between the design engineer and the system is located totally in phase 1, and is limited to preparing design data and directives required for the following design phases. The designer has no direct control on the rest of the design process which is carried out completely by the system. Making any design change means running the whole design process once more with new design data. An example of such systems is the MERLIN BRIDGE program[3]. The user of such systems should be a highly experienced design engineer able to supply the system with correct and sound data.

On the other hand, an adaptative CAD-process could be represented schematically as in figure [1-b]. The computation phase and the output phase are broken down into many subphases. The user can interact with the system to direct and control the design process at any point located between two subphases. He can either validate the results of the design at this stage of the design or direct the system backward to execute any phase with new design directives and data. Thus, the design process is highly interactive.



[a] fully automated CAD-process [b] adaptative CAD-process

Figure 1

A highly automated CAD-system is characterized, from our point of view, by:

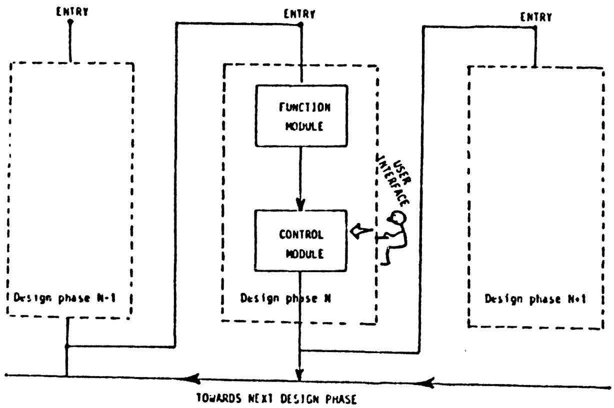
1) Providing an adaptative design process which passes automatically all design data from one subphase to another. The user should be concerned neither by the way these data are passed nor by their internal representation. He should only be concerned by the design alternatives and issues.

2) supporting the design of integral problems; that is an integral project or an integral part of a large scale project.

In order to assure a high automation level, as defined hereabove, the system OMRAN has been developed around two key notions: the design phase and the project context. The design phase represents the basic functional element of the system, while the project context corresponds to the logical environment of the design process.

The design phase is normally composed of two logical modules (see figure 2.) The first module is called the function module and corresponds to some function in the system. It has an entry point which is also the entry point to the whole phase. The second module is called the control module and has an interactive interface with the user. The role of this module is to determine which design phase is to be executed in the next step according to user directives given to it through the interactive interface, and to perform all necessary actions to pass from the current design phase to the next one.

Thus, if the order of the current design phase is N, and the user validates in some way the results obtained up to this point, the control module will pass the execution to the design phase N+1. Otherwise the control is passed to a previous design phase in order to allow the user to modify design data and re-execute certain design phases. This provides the user with complete control of the design process with minimum overhead.



DESIGN PHASE

Figure 2.

The project context reflects the integrality of the design process for a given case. Any design session using OMRAN system should be carried out, imperatively, in the context of a given project. A project might include the design of one or more buildings, and the building itself can be composed of more than one structurally independent "part".The part is the basic design unit in the system.

Each project is indentified by a unique name, which serves also as a complementary identification to all data belonging to this particular project, and by a set of general data assigned to it wich describe the general characteristics of the project.

4.2.2. System architecture

Designing a whole project might be extremely long, and cannot be achieved normally in one designing session. Thus under the OMRAN system, the designing process has been divided into independant design sessions. When the user initiate a session he should first choose his design context, i.e. a project, and then he can execute one or more design phases. The function module in each design phase should be assigned to a specific function belonging to one of the following types of functions:

- Adding or modifying design data.
- Computing and controlling intermediate results.
- Issuing final or temporary documents.

Since the system is based on the concept of independent design session all data are to be preserved between these sessions. A data base is assigned to each project to include all types of required data and in particular:

* General data including the number of stories, the number of parts, the physical characterstics of used materials, the design standard code, the method of design,...etc.

* Geometrical information including the number and position of axes, distribution and types of slabs, positions and dimensions of beams, positions and dimensions of columns and walls, dimensions of all elements,... etc.

* Magnitude of all externally applied live and dead loads on slabs and on other elements in some particular cases.

* Magnitude of all internal loads transmitted between elements which are the intermediate results of the design steps.

The data base assigned to the project is identified by the name of the project.

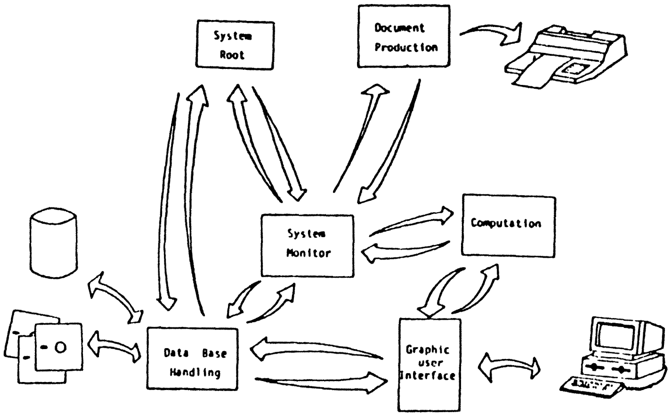
Although the function module is the basic logical element of the system, it covers normally a partial function and its size is too small to form an independent module. Function modules of similar types are grouped to form main modules and these main modules represent the skeleton of the system. Figure 3 shows the architecture of the OMRAN software. It is composed of 5 main modules and a system root. The main modules are:
The system monitor plays a central role in the system. It interacts intensively with the other modules to coordinate their cooperation and preserve the overall integrity of the system.

The data base handler is charged with the management of the data base. It receives the requests from the monitor or the user interface module and provides them with the required stored data, or it stores the data delivered to it in the data base. No other module has direct access to the data in the data base.

The user interface module is the module that takes of charge the interaction between the user and the system. It includes mainly the control modules of the different design phases, and the function modules for data entry and modification. It also groups all modules dealing with graphic display and graphic data entry . A more detailed description of the functions of this module will be given when discussing the man-machine interface.

The computation module is the module which contains all the algorithms used for the design of the different elements of the construction. It interacts only with the monitor and the user-interface modules.

The document production module is the module that outputs the temporary or final design documents which are in their quasi totality production drawings. It thus contains the programs for plotting these drawings.



The organisation of OMRAN software.
Figure 3

All of the main modules are implemented using the overlay technique. To simplify this implementation a system root was separated from the monitor and implemented as a resident module.

4.2.3. The man-machine interface

OMRAN's man-machine interface can be considered as a distinctive feature of the system. The dominant idea in designing it was to obtain an interface suitable to be used without difficulties by structural engineers who have no (or very little) background in computers. To achieve this objective it was necessary to adhere to the following principles :

1)The interface should eliminate the need for any initiative that the system might require from the user during the design process. All initiatives should come from the interface and the user only has to choose between proposed alternatives or to supply design data .

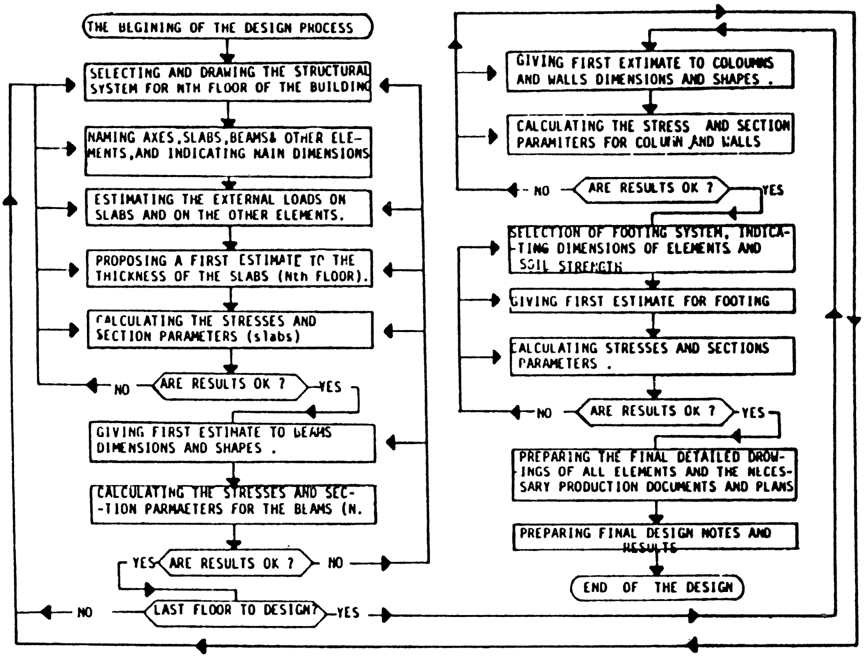
2)The CAD-process should follow as close as possible the manual design procedure. It should follow the same design steps and apply the same rules and terminology. This would garantee the naturalness of the interface .

3)The man-machine interaction should be as clear as possible and the way of displaying information should permit no misunderstanding and should be free of ambiguity. It must also provide the means to verify the conformity of the input data and to inform the user clearly about the errors he makes.

4)The user should have the possibility to access any design data or partial design results at any point of the design process. He should obtain this information in a condensed and expressive from.

5)The man-machine interface has been based on the concept of menu. A number of menus were assigned to each control module of any design phase, and all the man-machine interaction is strictly limited to these menus. Thus, the man-machine interface becomes no more than the succession of these menus. The windows capability of the micro-computer is used extensively in constructing these menus . A fixed window was choosen to display choice alternatives and the current design status, while other dynamic windows were used to display information and results (alphanumerically or graphically) and for data entry.

It is very important to analyze and to model the manual design process before conceiving a natural man-machine interface for a CAD-system. The manual design procedure for the design of reinforced concrete buildings was thoroughly analyzed and the different steps of the design procedure were identified . Figure 4 shows a simple flowchart for this procedure.



Flowchart of the manual design process.
Figure 4

OMRAN's man-machine interface is modeled on the above mentioned flowchart. For each step of the manual process there corresponds a set of design phases that perform the same functions The menus assigned to these design phases are conceived to give the user the control of the design process in a way very similar to the manual design. Thus the naturalness of the man-machine interface is guaranteed and the productivity is increased.

An important aspect that contributes also to the naturalness and the clarity of the man-machine interface is the extensive use of graphics. It is well know that the information content of a drawing is far greater than that of a descriptive text and less ambiguious. Engineers are very keen in using and understanding drawings and are less familiar with descriptive text. The graphic dialogue is the natural dialogue for them .

A main strategy in designing OMRAN's man-machine interface was to substitute, whenever it seemed possible, any prompted text in the menu by a graphic prompt. To illustrate this more clearly, let us suppose that the user has to choose between two types of beam sections: a rectangular section and a T section. A text prompt would likely be:

" Choose section type; rectangular = 1
T Section = 2

In OMRAN the prompt will be the display of the rectangular and the T sections as shown in figure 5 . After choosing the section type, the dimensions of the section should be specified . The system will prompt:

(b, h) ?

The user has only to answer : (40, 120) for b = 40, h = 120, while B and t are calculated automatically from slabs data.

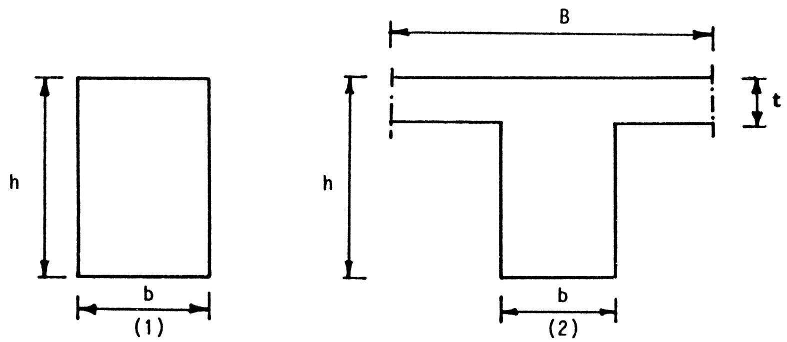


FIGURE 5

Another important strategy is to provide an immediate reaction to all user directives and especially for the modifications he carries out on the drawings. This means that the user will see immediately the results of the modifications he introduces on design data.

Component are described very briefly hereunder to help understand the major features of the interface. This component is built like the other components in the form of a graphic dialogue using menus. The first of these menus asks the user for the number of axes in both directions, then it displays a first draft of the axes grid containing the specified number. The dimensions between these axes are then entered and a new axes grid is displayed fitted to scale. The next step is to indicate through the second menu the position of all columns on the axes grid. This is done by moving the graphic cursor between the nodes of the grid. At each node the user can insert or delete a column by a simple key-press; he should continue until all columns are introduced.

The system proceeds then in specifying the positions of the beams.The axis of any beam is supposed to coincide with an axis of the grid; if not, it should be added to the grid. Indicating the position of a new beam is very simple and consists in positioning the graphic cursor at the node corresponding to one of the beam ends, pressing a particular key, then moving the cursor to the position of the other end passing by all intermidiate nodes and pressing again at the end the same key. The beam appears immediately on the grid at its position. Deleting an existing beam requires an identical procedure using another dedicated key.

Slabs, cantilevers and walls are introduced and specified in a very similar graphic way. The user obtains at each stage updated drawings containing the accumulated information and he could modify any one of them. When the definition and the specification of the structural system of the floor is completed, the user could store all the information in the data base and proceed to a new floor or begin the design of the elements of the floor.

4.2.4. Production dócumenations

Automating the preparation and the issue of production documentation, i.e. drawings, calculation notes, ...etc., is one important feature of the system OMRAN. This is essential for increasing the productivity of the design engineer on one hand and to assure the consistency and correctness of these documents.

Three types of documentation are outputed by OMRAN and these are:
- -Reports and calculation notes.
- -General drawings like layouts,structural systems,columns, ...etc.
- -Detailed drawings of the elements, slabs, beams, columns, footings, ..etc.

Each type of these documents corresponds to a particular need.

The calculation notes are the basis for later verification of the correctness of the results . The two other types are production tools to be used either directly or after proper reproduction in some different form.

The user might require the output of each one of these documents during the design process to obtain a working document or at the end of the design process to get final drawings. An optional feature to be included in the system in the near future is the use of a large drum plotter. In this case final drawings need not to be reproduced and the plotter could be shared between many work-stations.

An example of calculation notes produced by the system is shown in figure 6. It includes the design results of a continuous beam. The loads transmitted to the beam from the slabs or the other elements are plotted first then the envelope for the bending moment and shearing force are drawn and finally the dimensions of the sections and steel information are shown.

In figures 7 and 8 two examples of the general drawings are illustrated. Figure 7 gives a structural system plan and the reinforcement of the slabs in this plan, while figure 8 gives the layout of the columns. Finally figure 9 is an example of the detailed drawings produced by the system. It shows all the details necessary for manufacturing a beam.

5. Conclusions

The first version of OMRAN has been experimented with conditions very close to normal operational conditions by some novice engineers who have slight knowledge in computing. The results of this experimentation indicated the following:

- The system is very effecient for the design of ordinary types of reinforced concrete buildings, and less efficient for special design cases which are not common .

- The increase of the productivity of the design engineer is in the order of (5-10).

- The man-machine interface is very simple to use and quite natural.

- Very little training is required to use the system.

In considering the above mentioned results and the low cost of the system, it becomes clear that the design considerations retained in our work are interesting and that micro-computers introduce new dimensions in the design of turn-key CAD-systems destined for wide-spread use.

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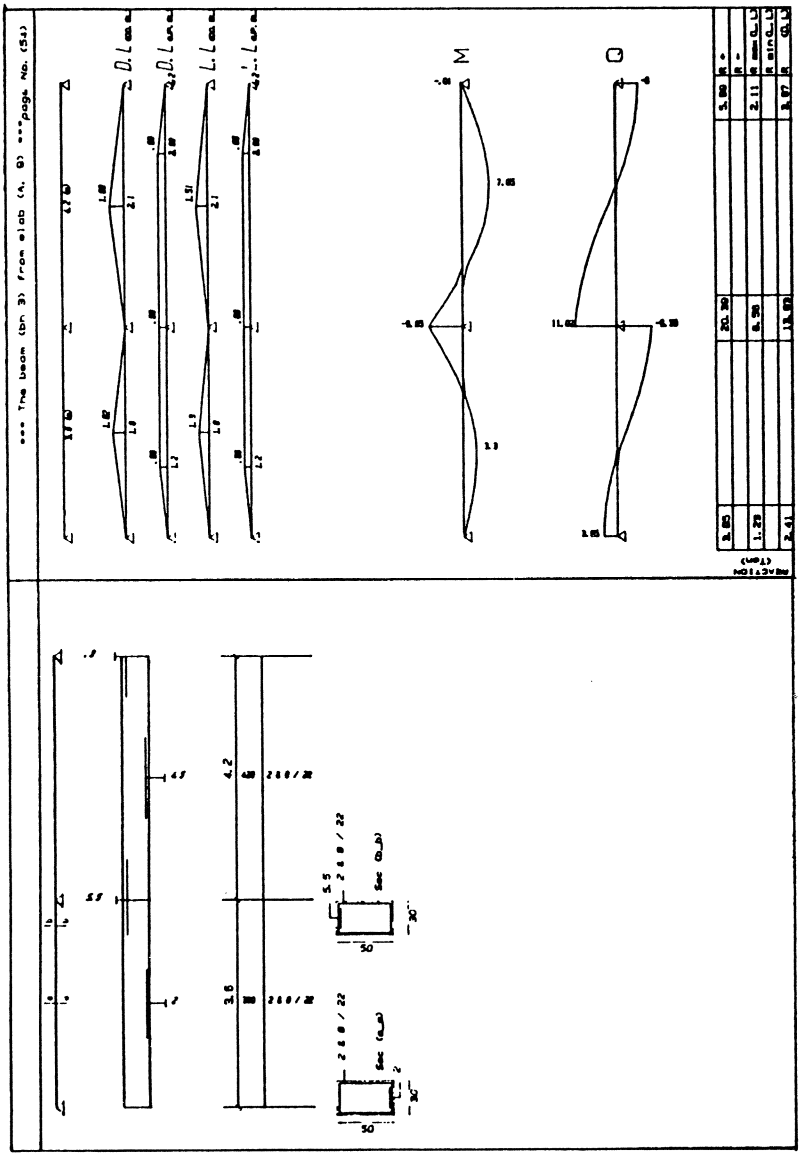

Figure 6

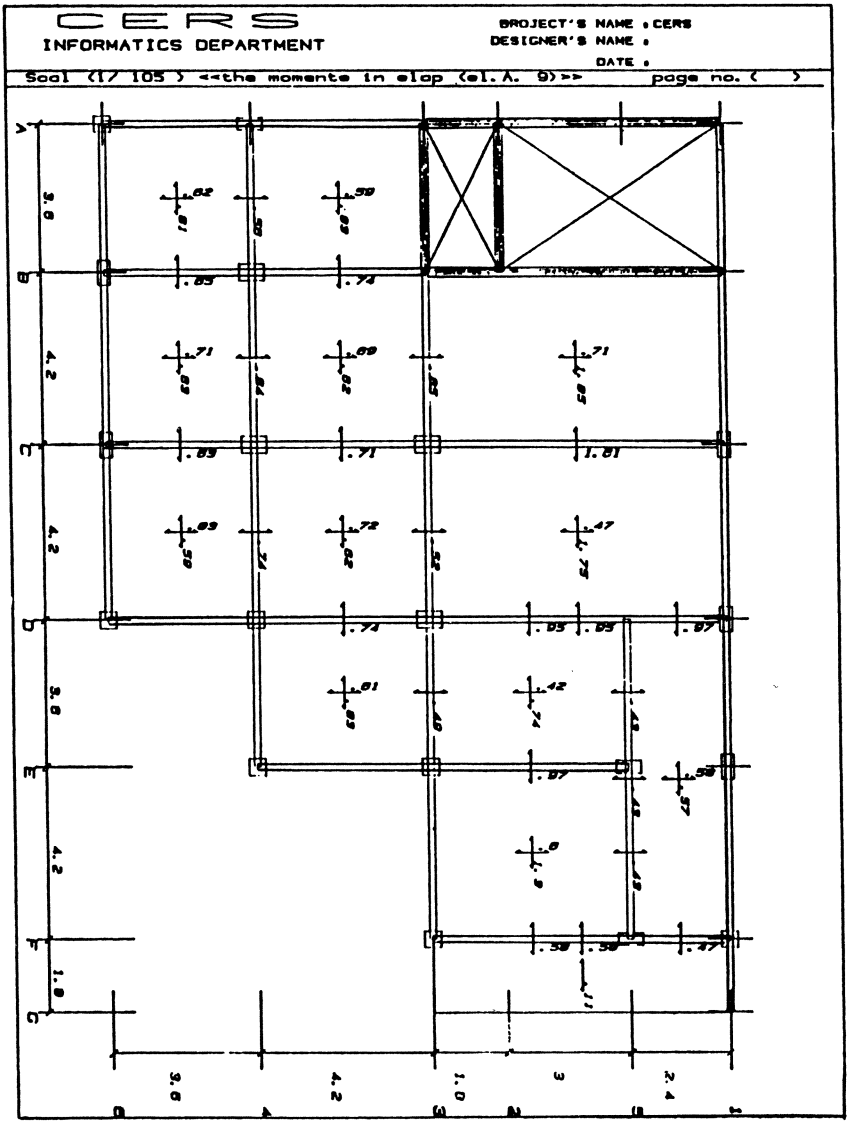
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Figure 7

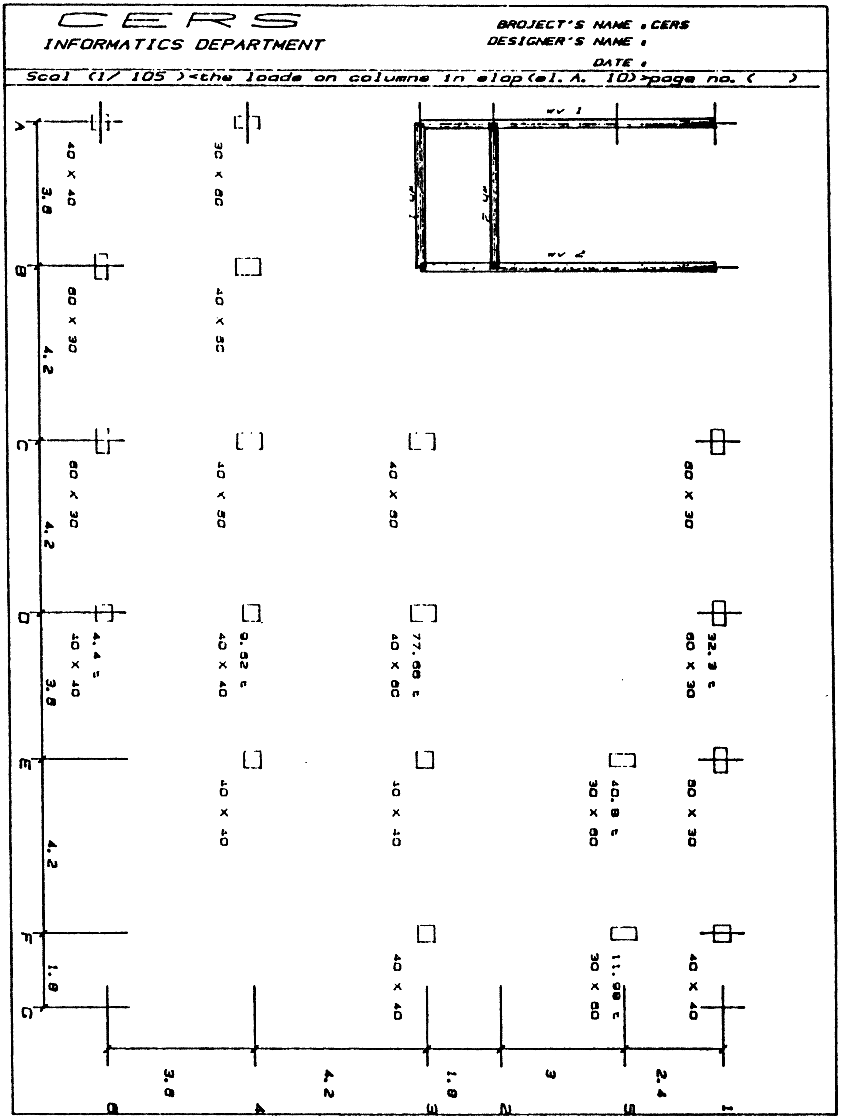
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Figure 8

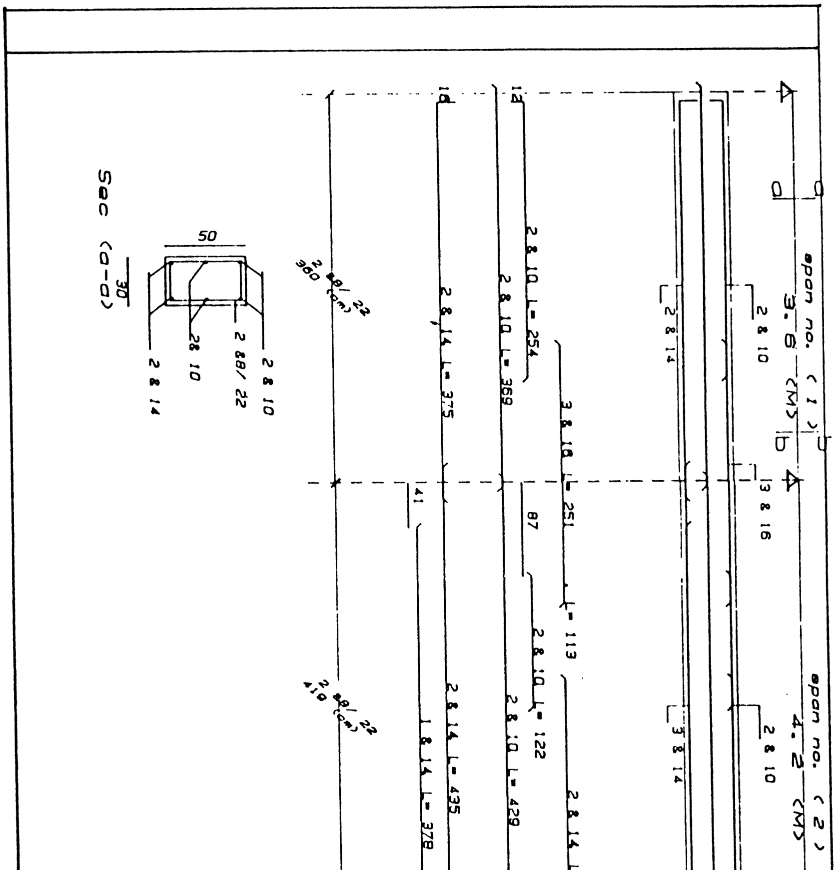

Figure 9

Affordable CAD
But is the £ 10,000 Workstation Capable?

E.D. Forrest

ABSTRACT

American architects and engineers seek "affordable" CAD--see it as the small organization's passport to automation of design and construction.

With IBM's entry into personal computers, CAD technology evolves in a great rush and, fortunately for all, applications software to fill thousands and thousands of these tabletop PC-CADs manages to keep up.

Presented is an update on capabilities of such FFr100•000. workstations and how the American experience could be useful to French confrères. Listed are sources for learning more.

I see in the promotional materials for this conference, MICAD 85, stress the applications of computer graphics. They also suggest: "Here's the next industrial revolution--it's happening now!" An understatement indeed; even in Europe, which gave the world the original industrial revolution.

To the architect, the engineer, the manufacturer, the fabricator, the constructor, computer graphics is behind that revolution and it is spelled C-A-D computer-aided design (CAD) and computer-aided drafting (the other CAD) are so magical, the results often beg belief. Now hear this, if you please:

1. What's in store for engineers? for builders?

This editor will, he believes, in the next half-hour offer some proofs the 1985 models of low-cost workstations can do much for your design-drafting needs.

He is mindful of European software developments as far back as the 1960's--well before Sutherland at MIT gave life to interactive graphics. While the US electronics industry first, the aerospace industry next, enjoyed the benefits of interactive CAD-- at FFr1•950•000. workstations mind you-- we US architects and engineers:

- o Didn't believe your structural analysis programs, your hydraulics analysis and computation programs etc did what they appeared to do; also, disliked the-let's-wait-and-see-if-it-comes-out-right vagaries of batch processing;

- o Looked over the shoulders of the US electronic engineer at CAD consoles and wondered if some of that interactive, instant-replay magic would ever serve us, if we could ever afford it that is.

We were envious too as COMPAID and PDMS for process plant design and documentation, then GDS and BDS, then ROMULUS and EUCLID, then DOGS, BOXER, FIDO, SNAKES, MARMALUKE and WOLFHOUND for all kinds of architectural and engineering design and drafting poured out of Europe. Why couldn't we write such software? Better--why couldn't we meld these good products with truly interactive workstations?

It took organizations like MATRA, DESSAULT, CV, INTERGRAPH, to name a few, to finally offer such tools to architects and engineers (A&Es). That state of grace however did not appear till about 1980, or so. Price: about FFr900•000. (US$90,000.) per workstation seat. Only the well endowed firm would dare afford such CAD.

Isn't it incongruous, that as of this month, in all CAD/CAM applications worldwide, and since 1969, just 88,000 such expensive workstations have been sold. Isn't it staggering to consider that since the IBM Personal Computer first appeared in 1981, followed by all those DOS-enabled clones, that 5,200,000 PCs were sold in just one year: 1984. The year before that it was 2,500,000. Each of those years, by the way, IBM took 33% of the market.

But, observe, it's 900 000. versus 90 000. francs per workstation. Therein lies great promise for us users--and software is the secret.

<u>Rise Of The PC Workstations:</u> ELSEVIER the international publisher had a hand in originally establishing in the UK[1] a computerized database of worldwide computer programs. It's informative to note the rate of new software propagation as reported in its quarterly catalog of microcomputer software:

Table 1

Microcomputer Software: Growth Patterns

Edition	No of Software Vendors	No of Software Programs
1983-Fall	2,639	9,470
1984-Spring	2,961	10,757
1985-Winter	3,009	14,234
1985-Spring	3,598	17,530

Source: "The Software Catalog: MICROCOMPUTER, Winter 1985"

1 Called THE INTERNATIONAL SOFTWARE DATABASE, it's updated daily. The service now operates out of Fort Collins, Colorado in the USA.

Herein lies the fruition of what IBM knowingly, or perhaps unknowingly, promised: CAD For Everyman. The FFr65•000. to 130•000. tabletop hardware, charged with CAD software, at prices beginning at 7•000. per application, means CAD is truly affordable for most professionals.

The Biggest Seller: AutoCAD: But you say: is it real? If one spends the equivalent of US$2,000. for certain enhanced CAD software called AutoCAD from San Francisco's AUTODESK INC--currently selling approximately 1,600 packages a month--the question is: will it perform real work? Can it draw real drawings? The answer: yes. The provisos: few.

Here are words from Victor E Wright, a professional engineer with LUCKETT & FARLEY, an A&E and construction management firm in Louisville, in the US:

> "4D CAD. Four-dimensional CAD systems? No, four-dollar-digit CAD. That's right. You can have a working computer aided drafting system for less than [US]$10,000. For those of you who look at the price tag before you kick the tires, here's a quick summary:
>
> - o IBM Personal Computer with accessories: $3,850.
> - o Houston Instrument DMP-42 Plotter: $2,995.
> - o AutoCAD, a CAD program: $1,500.
>
> TOTAL: $8,345.
>
> "For the skeptics, we will concede immediately that this system will not do every thing a $500,000. CAD system will do--it' not magic. For instance, our system will not handle simultaneous output from 50 production people and print full-sized drawings of an airplane wing all at the same time. Nor is it a three-dimensional system that can check all the interferences in a 50-story office building. Nor will it store all the drawings of a nuclear power plant on disk memory. But it is a CAD system nonetheless--one that will handle the needs of many drafting operations.
>
> "This system is for the small engineering shop, the engineering department of a small industrial firm, or perhaps even the plant engineering department of a fairly large industrial firm or utility company. It offers many (not all) of the features currently offered by systems costing much, much more. It brings computer aided drafting to a single user in the form of a system that can be used for other tasks when there is no drafting to be done. The system is an excellent training system because it does include the features offered by the larger systems just a few years ago. It is practical, affordable and real..."

The key words: 'excellent training system', 'practical', 'affordable', 'real' I find used again and again by the newly initiated micro CAD user. Especially the AutoCAD buyer gaining, if you please, a new Peugeot Turbo and then some, with the difference between 90•000. and 900•000. francs.

Mr Wright summarizes as follows:

> "What won't our system do? If it didn't have some drawbacks, there would not be a market for the larger systems. Since this is an objective article, we will examine the limitations.

"Our system is strictly a single user system, although several systems could share a common Winchester hard disk drive for more economical storage. If you want a single system that will accommodate 30 or 40 production people, you would spend $300,000. or $400,000. to equip each one with his or her own system. A larger, multi-user system would probably be a better choice.

"The resolution of the screen display of our system is limited to that of the host computer. Of the micros supported by AutoCAD, probably the Zenith Z-100 has one of the better displays; even it will not compare to the large high resolution screens of a six-digit-$ CAD system. We can add a supplementary display to our system and achieve a significant increase in resolution, but that would take us out of the four-digit price range (but not by much).

"The plotter included in our system will not accommodate bed-sheet sized drawings. Again that is a budgetary limitation not a limitation of the AutoCAD program. If the budgetary constraint is relaxed, a large plotter can be included in the system.

"Our system is not a three-dimensional system, so it will not check interferences for us--it has no way to know whether two objects occupy the same space. We can use AutoCAD's features to make the task of checking interferences easier than it is with manual methods, however.

"Considering the cost of CAD systems only a few years ago, our system represents a major breakthrough. It offers many features of systems costing ten times as much. For a small firm or department that can't justify a $100,000. system regardless of the advantages CAD systems offer, our AutoCAD-based system may be the only way to realize the benefits of computer technology in design and drafting."

Then There's VersaCAD: Also from California, for 2D and 2-1/2D drafting, is the world's second-most popular low-cost workstation software. AutoCAD is first, with about 14,000 sold; VersaCAD stands at 4,000. Both are priced about the same for roughly equivalent performance: FFr26•000. versus 25•500.

In an invaluable 1984 review of CAD systems and software priced under $15,000., the American Institute of Architects masterminded procedures, a group of 14 small (and a few large) A&E firms did the testing, and the journal, ARCHITECTURAL TECHNOLOGY, published results (Fall 1984). The packages tested and their ratings:

- VersaCAD 2
- CADPlan 2
- MicroCAD 3
- AutoCAD 3
- RoboCAD 5
- Drawing Processor 5

Unlike Olympic pairs skating or gymnastics scoring, the closer to 1 the rating, the "better" the software, say the evaluators. But even more useful than saying "learning CAD on micros is good", are the numbers in the following table from that AIA review: (Source: 3/D INTERNATIONAL, a Houston A&E firm; staff=340.)

Table 2
Comparative Costs For CAD
(US Dollars $)

	Plain Micro	Micro CAD	Mainframe CAD
Hardware & Software	$5,000.	$12,000.	$900,000.
No of Workstations	1	1	8
Per Workstation Cost	5,000.	12,000.	112,500.
Monthly Amortization	83.	200.	1,875.
Monthly Maintenance	2.	10.	872.
Total Monthly Cost	85.	210.	2,747.
Cost per Hour (One Shift)	$0.50	$1.22	$16.00

Dare now any engineer or constructor say he can't afford 12 francs per hour to have on standby a low-cost CAD workstation?

2. And for the architects?

At last count this editor finds 38 organizations busy creating software "guaranteed to make any architectural practice automated". Fat chance--since most of them overlook the realities of the architect's world. Namely:

- o At least 85% of these professional firms are small--small in workload, small in staff.
- o Commissions for the firms are cyclical at best, non-existent too often.
- o Purchase of automata for the design room is equated to robots on the assembly line--"please, no mechanization here, we're creative artists..."
- o Most of these professional firms can't afford the big INTERGRAPH solution, the big COMPUTERVISION solution, the big APOLLO/PAFEC solution etc.

Is the low-cost CAD workstation likely to succeed here? Oh yes. But first, this disquieting news from across the Channel:

Last autumn, high over the Atlantic homeward bound from Amsterdam, with the Sunday Times (30 Sep 84) spread wide, my eyes popped as I read how fares the practice of architecture in the United Kingdom:

> "Leading architects have welcomed a plan to limit the number of new entrants to their profession by closing up to eight of the the country's 36 schools of architecture by 1989 and placing an immediate ban on any further increase in student numbers on the rest.
>
> "The plan published jointly last week by the University Grants Committee and its polytechnic equivalent, the National Advisory Board for Local Authority Higher Education, calls for the outright closure of four polytechnic schools and for mergers that would cut the number of students completing courses by 40%. But even these drastic cuts would not stop the number of registered architects, already at an all-time high, from reaching 31,000 by the end of the decade.

"'The urgency is very great', says Alan Groves, Cornwall county architect, and the senior representative of the Royal Institute of British Architects on the working party chaired by Lord Esher that drew up the report. 'If nothing is done now, our problems will get very much worse'. What worries Groves and the Institute, which pressed for the establishment of the Esher committee, is the widening mismatch between the number of architects and the work available.

"Between 1973 and last year, the number of architects registered in the United Kingdom grew from 22,400 to 25,814, yet the value of construction work dropped 25%. In real terms the value of building output available per architect plunged from £707,000. to £393,000. in one decade.

"Unemployment in the profession stands at less than 4%. But the laws of supply and demand have made architects among the most poorly paid of professionals. For salaried architects, average earnings last year were £9,413., a drop of 20% since 1973, allowing for inflation..."

And the view from America? Here are words from an interview in the McGraw-Hill ENGINEERING NEWS-RECORD (29 Nov 84) with a ranking member of the American Institute of Architects:

"In the future, graphite pencils, old dogs who can't learn new tricks and entry-level architects who spend time crosshatching brick on drawings will be OUT. IN will be drastic changes in architectural practice, computer-aided design (CAD) and firms that emphasize scheduling and cost control.

"So predicts R Bruce Patty, a principal in the firm Patty Berkebile Nelson Associates architects Inc (PBNA), Kansas City, and the next president of AIA. He will be inaugurated in Washington next week. Patty believes that computers are the most significant change in architectural practice 'since the invention of the T-square'. And as architects are coming to grips with computers and the capitalization they require, he believes they will be taking a hard look at the business side of their practices...

"The standing of PBNA in the Kansas City community can be reckoned by its growth. The firm has grown 125% since 1981--from a staff of 22 to a staff of 50--making it now the largest firm in the city...

"In addition to office buildings the firm does development planning, space planning, interiors and rehab work...

"PBNA is esconced in the computer age. It bought a micro for cost estimating, scheduling, space planning, spec writing and financial management in 1980, and its first color computer-aided design workstation [from SIGMA DESIGN, Denver] in 1983. 'We took the approach that we didn't want to use the CAD system as a support instrument for construction documents and working drawings. We wanted to explore the realm of design', Patty says.

"Further, Patty says it could be concluded that if architectural offices provided only the same services tomorrow as they did yesterday, then computers would mean smaller staffs. 'But most architects will be expanding their services', he says, 'into interiors, facilities management and construction management'. Entry-level professionals, with five to seven years of schooling, however, 'won't be spending time dotting poched concrete patterns. The computer frees us from that drudgery and allows people to apply their creativity'.

"Young architects are a concern of Patty's--what they are learning in school and what they are earning as they start their careers. AIA recently surveyed earnings in the firms of its members. The compensation of principals averaged $53,000. a year. 'I'm more concerned with the low salaries paid to entry-level professionals--an average of $15,000. a year', says Patty. Part of the long-range solution is in schools of architecture that now teach students the business of design."

Where lies the truth? Close down architectural schools? Limit the number of new professionals? "Computerize" the few allowed to earn degrees? Reads a little like something the Luddites, the stocking frame smashers, might have fostered, doesn't it?

Shouldn't we grab on to every low-cost workstation we can afford, equip every Tom, Dick and Harry of an architect and engineer in sight, and let the cream float to the top? Human ingenuity has a way, you know, of delivering unexpected bonuses.

If American architects and engineer-builders are being advised to proceed into automation with the assurance all will be well, why should you French be timorous?

SUMMARY: Be resolute. Be confident. Affordable CAD workstations are capable. Demand them. Expand your professional horizons. Acquire 1985 capabilities. Make your peers tremble in awe.

As a user of CAD expect more and more software innovations to inundate you with choices. As they say in New York: you ain't seen nuthin yet. Be aware: soon affordable micro CAD will be replaced by affordable micro EXPERT SYSTEMS.

As a supplier of CAD, give up trying to invent the ultimate, low-cost, PC-like workstation. Concentrate on uncovering software sources. Expect the Japanese to take over and re-create CAD hardware delivery systems--ever less expensive, ever more useful.

As a vendor or retailer of low-cost workstations don't expect design and drafting management to come and clean off your shelves. You must go to them. You must sell them. But once committed to your technology, we architect and engineer types remain loyal to the first brand which taught us how exhilarating automation can be.

Et, bon chance.

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CADCAM in the British Construction Industry

I. Hamilton

Construction Industry Computing Association (CICA)

The widespread publicity given to the term CAD/CAM would imply that 'it' is generally available and useable by all branches of industry. As far as the Construction Industry is concerned this is a gross oversimplification. The aim of this article is to attempt to firstly define CAD (and to a lesser extent CAM), and secondly to give at least one view on the CAD/cam scene in Construction in the UK.

There are now substantial sums of government money available to help firms find out more about CAD/CAM. The Department of Industry administers a CAD/CAM fund of several million pounds aimed at providing finance for such things as information data banks and training and awareness schemes. To date little, if any, of this money has been made available for the Construction Industry. While part of the reason for this may lie in the fact that a separate Ministry the Department of Environment, rather than Industry, has the sponsorship role for Construction, the varied nature of the Industry and the different ways in which it can use CAD/CAM systems makes it difficult for individual organisations to make the type of submission required for the receipt of these funds.

Computer Aided Design can be taken as embracing all forms of technical computing ie everything other than accounting and other standard data processing work. Thus a CAD system can be anything from an inexpensive micro being used with a small program to calculate the heating requirements for a building to a large mini (realistically a main frame) being used to perform large complex analysis of oil rigs. This appears to be rather different from other industries where a CAD system usually seems to mean a turnkey draughting system. While this may be viewed as an oversimplification on both counts it hopefully helps to indicate CAD has no unique definition.

The term CAD/CAM appears to have taken over from plain CAD. This only helps to confuse the issue. One of the main reasons for firms considering investing in this type of computing is to find out if it will increase their competeviness. For manufacturing industries design and production are generally carried out by the one organisation, hence the possible benefits of CAD/CAM. The ability to link design information with numerically controlled machines, materials ordering systems or even robots can potentially give good returns. For the Construction Industry design and construction are usually carried out by different organisations, and very little use is made of numerically controlled machines or related devices.

The one major exception to this last statement is in stuctural steelwork fabrication. Structural steelwork is often seen as bridging the gap between the building and manufacturing industries and is sufficiently individual to have its own Constructional Steelwork Sector Group within the UK NEDO organisation. This NEDO Group has published two relevant reports. One deals with machine tools and the other with currently available computer programs. Even in this area design and fabrication are usually carried out by different bodies. The design is carried out by a consulting engineer or other design authority and the fabrication and erection by the specialist contractor ie the fabricator. Computer programs are available to aid in both processes but very little practical success has been achieved in developing an all embracing program to run right through from structural analysis and design to machining of the basic steel sections. The reasons for this are more the divisions of responsibility for the different parts of the operation rather than any insurmountable computing problems.

A smaller but growing area with close similarities to steelwork is that of timber framed buildings. Here few of the problems of organisational boundaries exist and successful highly customised CAD/CAM systems have been developed and put into use. The growing use of this type of construction particularly in house building could increase the impact of this particular use of CAD/CAM.

For the vast majority of organisations involved in building and constuction CAD/CAM as such has no real place as yet. Great changes would have to take place in the way in which the industry is structured together with a minor revolution in the methods of construction themselves before CAD/CAM as it is found in the manufacturing sectors could be directly applied. To both the potential puchasers and suppliers of what are currently termed CAD/CAM systems it is important that this fact and the major reasons for it are properly understood. This should not be taken as meaning that firms in the Construction Industry are not buying such CAD/CAM systems but rather that the way in which they are capable of being used and benefits obtained are different to those shown in some of the glossy literature distributed by suppliers. An indication of the extent to which these types of systems are in use in construction will be given later in this article.

It may be helpful to describe briefly the way in which the United Kingdom Construction Industry is currently structured. In both Europe and the United States the structure is different, this can make direct translations of potential benefits difficult, a fact not always appreciated by suppliers. In the UK design and construction are usually treated as two separate functions carried out by two separate organisations, or groups of organisations.

The major participants in design are, Architects, Civil and Structural Engineers, Building Services Engineers, and Quantity

Surveyors. The extent of each groups involvement (if at all) depends on the type of construction project. In most large projects the picture is further complicated by the fact that each participant is probably a separate company cooperating with the others for the duration of the project. Again there are exceptions to this. Projects are carried out on a design and construct basis with one organisation doing the lot. Design organisations can be multi-disciplinary, and in some cases part of the client body, eg the Property Services Agency of the Department of the Environment. However the majority of projects of any size tend to be designed by a combination of organisations representing the different professions. A further distinction between construction and other industries is that the 'client' is usually one individual or organisation who meets the total cost of design and construction and that the 'product' is a single entity albeit a multi- million pound building or other works.

Typical clients are insurance companies, public bodies, oil companies, and the retail trade. One of the effects of this is that any one combination of design organisations may in turn work with any one construction company for one client for only one project. The ramifications of this in terms of the difficulties of obtaining many of the much vaunted potential benefits of CAD are considerable. An example of this is that both the architects and the structural engineers for a large airport terminal building currently being designed are using computer draughting systems for the work. This, one might think, would be a good opportunity to achieve the benefits of exchange of data on magnetic media rather than as drawings on paper. However, unfortunately this has not been found to be possible in practice. Both each organisation is using a different draughting system and the two sets of drawing data are not compatible at any useful level.
It is possible that in time given the formulation and acceptance of standards for drawing data such problems will cease to exist. However, for the present, the only certain way to ensure compatibility is for all involved parties to use the same draughting system. While possible in theory, this is more difficult to achieve in practice. If none of the firms coming together to work on a particular project already have a draughting system then there may be a chance of them all being persuaded to make use of one particular system. One way of this happening could be if the client made it a condition of engagement and/or met the costs of providing the system. On a very large project this might be considered to be an acceptable overhead. It will be interesting to see if and when this approach is adopted.

The extent to which draughting systems have been put to use by the various professional groups is itself varied. At the present time the architectural practices are probably the biggest users followed at some distance by civil and structural engineers and at an even greater distance by building services engineers. The reasons for this distribution are several but one of the most significant is the ease with which currently available computer draughting techniques can be used effectively by each group. The nature, number, and inter-relationship of the drawings produced by architects make the facilities for repetition, selective extraction, and modification as offered by draughting systems of some use. The original success stories of computer draughting systems in architecture were usually based on large Middle East projects where timescales could be short, changes many, and fees potentiallv hiqh. There is no doubt that in this tvpe of situation draughting systems can be shown to be a cost effective tool. However, much of the current use of systems is probably on more modest projects and the economic and other justifications are different. To a certain extent the draughting system 'band wagon' has started to roll for architects, credibility has been established, and the question many architectural practices may be asking themselves is not, 'can these systems do anything for us?' but 'can we afford not to make use of one of them?'. A curious mixture of fear of missing out on something that professional rivals may have found, together with a wish to reap any financial benefits that might be obtainable, may be behind much of the professions great interest in this area.

Civil and structural engineers have been using computers for a much longer time than architects yet have been overtaken in the adoption of computer draughting. As has already been stated the main reasons for this lie in the drawings and the ability of currently available systems to produce them. While many civil engineering practices have examined draughting systems the majority have yet to find the economic and technical justifications for their purchase. One major requirement of civil and structural work is the ability to handle parameterisation. While most systems can offer this at a relatively simple level to be of any great benefit it must be capable of dealing with a large number of variables, sometimes defined by equations, and allow the use of conditional statements. All this is available to the skilled programmer using the source code of the system but it is totally unnaceptable to expect the end user to operate in this way. To date very few commercially available systems combine parameterisation with the more sophisticated screen drawing facilities. Typical areas of application of parameterisation are structural steelwork detailing and reinforced concrete detailing.

To the building services engineer there appear to be two main areas in which he could make draughting systems effective. The first is the ability to use the layering techniques found in most systems. This will not only allow the different services (water, electricity, etc) to be shown combined or separated as required, but will, in theory, allow the services engineer to receive the architects base plans in digital form to be fed directly into the system. This of course assumes that the same system is being used or that compatability of data is obtainable.

The second area is that of clash detection in three dimensions. This is no small problem and while solutions have been developed for piping as found in process plant and similar areas these may not be directly useable for buildings. In general the problems of three dimensional representation are much greater for buildings than manufactured objects and the 3-D facilities of many systems, while excellent for the application for which they were developed, fall short of that which would be required for simple effective use in building design. This is an area of great interest and the Department of Health and Social Security as the Government body responsible for hospital building has sponsored the development of a prototype system to deal with this problem.

So far no mention has been made of the quantity surveyor. In the usual course of his work he does not produce drawings but extracts and makes use of information from drawings produced by others. Certain types of information can be readily extracted, particularly objects which are themselves discrete components eg baths, doors, etc. Here the task is usually to count and list all identical components for ordering purposes. The automatic calculation of such things as areas of paintwork or volumes of concrete can be more difficult if not impossible at any general level.

Perhaps the biggest current obstacle to the surveyor's use of draughting systems is one of professional barriers rather than any unsolved technical problem. Currently he receives part of his fee for the preparation of detailed information on quantities etc extracted from the architects drawings. If this information can be produced almost automatically from the drawing data, the architect has then done this part of the quantity surveyor's job, and may feel entitled to claim part of the appropriate fee! The surveyor may, not unaturally, be reluctant to agree to this. In a multi- disciplinary organisation this type of problem should not arise and the quantity surveyor will in fact have been relieved of one of the more tedious parts of his work.
The authors own organisation has been involved in advising the UK construction industry on the use of computers for over ten years. During this time it has witnessed the growth of CAD from a more or less accademic pursuit to being used in earnest by building professionals with little computing knowledge. For the last four years it has carried out an annual survey of the systems in use. This information was obtained from the system vendors and gives a very good picture of the penetration of both CAD in general and individual systems in particular.

The total number of systems in use in construction in the period 1981 to 1984 were as follows:-

1981	63
1982	120
1983	170
1984	230

The detailed results of the most recent survey are given below.

System supplier	System name	number of installations UKci	UK	EUR	WOR	TOT	launch world/UK
ARC Ltd	GDS/BDS	75	75	14	111	200	1980
Arcaid	Arcaid	2	2			2	1984
BDP Computers	Acropolis	9	9	1		10	1982
CSC Ltd	CEADS-CADD	13	17	35	285	350	80/82
DeCAL	Stag II	2	5	1		6	1984
Design Comptng	Gintran	4	6	1	1	8	84/83
FEAL Ltd	Gipsys	8	9		1	10	84/83
Gable CAD	Gable	13	19	4	17	40	1981
GMW Computers	RUCAPS	36	37	5	10	52	1977
Intergraph	IGDS	40	75	175	1000	1250	70/80
Oasys Ltd	Cadraw	16	16	2		18	/83
Pafec Ltd	DOGS	12	160	35	70	265	1980
APPROXIMATE TOTALS		230	430	273	1495	2181	

UKci Construction industry installations in the UK
UK Total installations in the UK
EUR Remaining installations in Europe, excluding UK
WOR Remaining installations worldwide, exc Europe
TOT Approx total of worldwide sales
Launch Date of launch in the world/and the UK

It will be noted that some of the 'bigger' names are missing from the survey. This is significant and due to the fact that they have yet to make any great impact on the UK construction industry. Both Computervision and IBM were invited to provide information but failed to do so. While both firms can claim impressive worldwide CAD/CAM sales their current UK sales to construction are very small, both firms claim to be looking to construction as a growth market so it will be interesting to see the results of next year's survey.
The survey shows a marked preference for 'home grown' systems, with Integraph as the only American system to have made any significant impact. No attempt is made in this paper to record information on the ever increasing number of micro based systems.

The Construction Industry Computing Association intends to repeat this survey and it would be interesting to have any similar information on the use of CAD in other countries.

Computer Synthesized Pictures for the Architect and in Scenography

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ABSTRACT

This report illustrates some considerations on the conception and development of a new visual communication-oriented picture synthesizing system. Particular stress is laid on depth synthesis problems based on Leonardo's definition of perspective and on the role played by the shadows and the illumination model. The prototype affords a manifold understanding of space through a system of simultaneous frames provided with a style attribute. The frame definition as the evolution of the window/ viewport relationship is also discussed. Finally, some considerations on the architectonic space conception and on television scenography are expounded.

1. The computer synthesized picture as a language

The computer synthesized picture has now become an integral part of visual expression and communication media.
A comparison with television would show that also in this case we have a bidimensional communication of a three-dimensional reality: the planning of the shooting and of the scene are determinative for the communication efficiency. Like in a television studio all is fiction; every object is first rebuilt and then filmed.
The difference lays in the synthesizing instrument, in the software wich must provide both for the construction of the scene model and for shooting it.

Also in Computer Graphics,no matter what scene modelling techniques are used,the final result is a bidimentional synthetic picture.

There is consequently a communication problem, not so much because there is a change-over from 3D to 2D within the graphic system,but because the viewer's or user's visual intelligence is not living the space experience directly.

The picture synthesis expressing instruments are the traditional ones of visual arts.
We try to preserve the perception of formal properties through their reproduction or through a clever play of substitutions and contrasts which constitute the grammar of the communication language.
Computer Graphics is a visional model of object models; this is the reason for its versatility.
Computer Graphics is not only a new technique for solving particular problems; it is a language whiwh communicates through synthesized pictures.

According to this formulation, the ensueing research has aimed to give a basis to the representation of the visional model rather than of the object model.
Research carried out on perception and colour problems and on the present raster-scan technology has persuaded us that the representation of depth and a manifold knowledge of space are the foundations on which a new visual communication-oriented graphic system must be built up.

2. The synthesis of depth

2.1. The perspective

Depth is the missing dimension of any bidimensional picture.
Perspective is the language or the "symbolic form" worked out in centuries of history by arts and visual communication sciences to express depth on a bidimensional level.

The perspective theory therefore includes all the techniques aiming at replacing the perception of depth with other formal properties of a two-dimentional type.
To reduce perspective to amere projection technique or algorithm is a serious mistake. Very little space is given to perspective in Computer Graphics text-books where it is almost always connected with the clipping problem on the visual pyramid without being aware that the development of all the algorithms is centered around this problem.

The representation of depth and the working-out of a language capable of expressing it are amongst the main purposes of a picture synthesizing system.

The perception of the location in space is connected with the depth-to-height ratio where depth is the valuation of the distance along the optical axis and height is the valuation of the position of the object involved with respect to a level refernce surface, i.e. the visual angle.

There are two properties which affect the perception of this relationship:

1 - The size : smaller objects appear to be farther away. In fact scaling ratios change as a function of depth.

2 - The priority with respect to one's own field of view This priority can not be chromatic if the objects are

separate; it is consequently a matter of aerial perspective. If the objects overlap, the matter becomes more complicated.
It should be noted that we consider some properties, such as line convergence and other geometric properties as being secondary.

The aerial perspective and dimensional perspective are synthesized in the visual intelligence to produce a correct depth-to-height ratio of the object involved.

We have experimentally shown that property inversion changes the perception of the relationship between two objects and that the change takes place in the back-to-up way, depth being replaced by height.
The argument works both ways: if I want to get a "close-up" of a distant object I can "lift" it.
This principle is widely used in the composition of television scenography.

Depth perception is also one of the variables allowing objects to become perception units.
With these statements we only run over the history of painting again, skipping Brunelleschi's and Alberti's linear perspective stage in order to follow Leonardo's more complicated definitions.

"Perspective, as applied to painting, is divided in three main parts, the first being the reduction of the volume of bodies located at various distances, the second part concerns the diminution of the colours of said bodies and the third diminishes the perception of the appearance and boundaries of said bodies at various distances."

The requirements for a picture production system are well outlined and the types of algorithms are implicitely proposed.

Leonardo's painting theory allowed him to conceive perspective as a perception of the loss of information and vision as the group of mechanisms capable of compensating this loss.

2.2. Depth and frame-buffer in raster terminals

In the raster technology-oriented graphic system we developed the priority problem is solved by the use of a z-Buffer which has the advantage of storing depth information.

A second matrix marked F-Buffer stores information on the polygon to whith the pixel belongs.
It is possible to display:

1 - The synthesized picture

2 - The map of the suitably classified picture depths. (Fig.1)

3 - The map of the picture scales as the depth-to-focal length ratio of the shooting lens.

4 - The depth of field map for a certain lens stop aperture.

Although this method has the disadvantage of occupying a comparatively large amount of memory, it is interesting because it can be easily implemented on the graphic station and because it represents the natural utilization of the frame-buffer.

2.3. Clipping limits and depth of field

The field of view clipping limits may be automatically determined as a function of the type of objective, resolution and observed point by making them coincide with the focusing planes.

The characteristic parameter is the hyperfocal distance I

$$I = \frac{(DF)^2}{AF \cdot 2R}$$

where: DF : focal length
AF : objective aperture
R : radius of the circle of confusion of an out-of-field point. This parameter depends on the type of camera used.

When simulating shooting and projecting the set, the technical shooting conditions should be taken into account.

The deoth of field may used both to determine the framing by setting the clipping limits on the depth of field limits and for expression purposes by having out-of-focus pictures appear in close-ups or in the background.
The analysis of the picture and the subsequent production of maps may help to decide whether the shooting model and the objective are adequate.

If they are not, we can either change the objective or the scene or both. Thus, if we wish to reduce the perspective distorsion and maintain the expression of depth of a 28 mm. camera by using a 40 mm. we must scale down the scene by a factor equal to the 40-28 ratio.

2.4. Shadow, light and depth

The perception of depth is considerably affected by the shadows in the neighbouring space and by the illumination and colour in the far away space.

The accentuation of the relief in a bas-relief is a phenomenon caused by the clever modelling of the shadow-generating profiles.

A shodowless architecture is unreal. The shadow helps to resolve the depth/height ambiguity and being actually the projection of a second view, it brings us very close to the binocular and consequently three-dimensional vision mechanism.

If the shadow gives depth and height to the volumes generating it, light gives depth to the colour of the linear element surface.

In implementing our graphic system we started from Blinn's illumination model and from Crow's shadow generation model.

The problems to be dealt with are two: the geometrical definition of the shadow and the definition of its colour.

We shall refer once again to Leonardo's treatise on shadows:

"Shadow should be properly described as the mitigation of light , applied to the body surface. Shadow is the diminution of light, darkness is the absebce of light... Shadow is divided into two parts: the primitive shadow, which is the shadow attached to the body surface and the derivative shadow which starts from said body, goes up in the air and, if it meets with resistance, will stop at the spot where it collides with the figure of its own base..."

This is the exact description of the algorithm we have used.
Shadow is conceived as an extruded solid starting from a base consisting of the edges which separate illuminated faces from non-illuminated faces.
This shadow-volume is transparent and becomes visible only when it meets an opaque body.

In the system developed by us this principle is used to make allowance for the great variety of solid bodies present on the scene and to make the best use of the Z-buffer and the F-buffer.

The illumination calculation is based on Blinn's model which allows excellent management of the illuminated parts whilst a substatial alteration had to be carried out for the management of the faces in the shadow.

According to the existing models, in these cases, the whole surface would have a uniform illumination level equal to the diffused light. In this way however, the perception of the edges of the parts in the shadow of a polyhedron would be lost since they would all have the same colour.

The existence of a certain amount of side reflection was therefore simulated so as to obtain a penumbra effect and the perception of the darker side opposed to the side of the radiating source.

The original application of this model to a wire frame has produced a new style (light wire frame) with an extraordinary expressive effectiveness: depth perception has been increased.(Fig.2)

With our graphic system, both the sunlight model (parallel shadows) and the artificial light model (perspective shadows) have become feasible.

In addition, a certain degree of transparency is associated to the shadows so as to obtain coloured shadows (the way they are in reality).
The representation of relief is unimaginable without a light model. Photography technicians and cameramen are well aware of this fact, so much so that they work with at least three lights: one to highlight relief (key light), one to soften shadows (clipping light) and one to highlight contours (back-light). We are presently endeavouring to complete the system by adding these three simultaneous lights.

3. Multiple pictures in visual communication

A picture synthesis system has a particular importance for the designer and scenographer because it helps him to understand space.

Imagined space resembles real space in that it cannot be restricted to a single representation.

Architecture is perceived through a sequence of movements and courses or through characteristic points and multiple positions.
The creative process satisfies functional requirements by working out technical solutions which integrate a three-dimensional space into the users' temporary sight condition.
Thus,the image of architecture becomes and environmental experience where the relationship between "things" and the thing-man relationship intersect. Sometimes the former and sometimes the latter prevails.
Composition may prevail over the perception model or else the viewpoint whole will determine the composition.

To apply this dichotomy to classic or organic architecture means oversimplifying the issue. (In painting, cubists denied the uniqueness of perspective and used the simultaneity of the point of view to express the relationship between things whilst objectified light becomes colour. The illumination model, the light and shade effects accompany and stress the rhythms of the composition. Refer to Braque's and Picasso's 1908 landscapes and to Picasso's woman with a fan, also of 1908).

Also in the theatre the project leads to the construction of a three-dimensional environment but each spectator has his own vision.

In cinema and television however the project is used for the production of two-dimensional pictures or rather of two-dimensional picture sequences. The picture is a function of time.

Also in this case there must be, next to the shooting project, a project for the environment to be shot: either a real environment or one built on purpose.

In visual design, no matter how it is applied, tha passage from the environment to its figuration either in pictures or painting becomes the main communication tool.

We shall now see how the graphic system multiple picture concept and the framing concept proposed and used by us have evolved.(Fig.3-4)

4. Multiple window/viewports

The present generation of graphic systems tends towards the overcoming of the conception of a single window/viewport.

The graphic terminals of the eighties manage simultaneously several windows on the screen. Generally, this is due to the wish of having a variety of dialogue texts or areas next to the graphic representations.

This setup has found a natural partner in the raster technology and its field of application in office automation.

The multiple window setup was however already present in the early CAD systems but was indubitably reactivated by the delopment of the geometrical modelers. The possibility of building up an object by establishing certain relations between its projections rendered necessary the simultaneous presence of different views on the screen.

Generally, in these cases, the view will be a direct association of a 3D window with a 2D viewport.

Our own multiple view requirements are however more complicated since their main purpose is to assist in understanding and communicating space.

This is needed by the architect who endeavours to imagine space as a whole with respect to applications sequences which correspond to an equal number of perceptive sequences.

5. Simultaneous frames: Definition and attributes

In the production of pictures for communication purposes framing is an essential factor. Cutting is a continuous choosing between different frames.

We may then define the frame as the display on a viewport of a view of the scene shot with a virtual telecamera.

To ensure the necessary flexibility in editing the frames we have separated the definition of the views (i.e. of the virtual telecameras) from the definition of the viewports (i.e. of the virtual screens).
In practice there is no implicit association; this relationship must therefore be explicitly defined.

We have therefore worked out three separate tables:

- the first table contains the parameters which define the window,
- the second table contains the parameters which define the viewport,
- the third table contains the parameters which define the frame,i.e.
  . the view pointer
  . the viewport pointer
  . the physical device or workstation.

A frame may thus be altered by changing at least one of the three parameters mentioned above.

More than one frame may refer to the same view or to the same viewport. The frame is obviously affected by the changes made in this basic definition of the view.

These flexibility advantages are enhanced by the possibility of defining frame attributes.

Three categories of attributes may be associated with each frame:

1 - A frame may be turned on or off or may be assigned a certain degree of priority with respect to other overlapping frames.

2 - The style of the representation.
The term style means that the frame may be represented as a wire model, with or without hidden lines, or that it may be represented in colours, with or without an illumination model, that shadows are displayed or not.

The'style' of the frame is an option of procedure and expression. Each style involves different and more less expensive processes. The definition of the style is an important point in graphic software design.
In addition, the efficacy of a style as regards the communication of certain formal properties becomes a crucial feature.

New styles may originate from new algorithms or from the original combination of existing procedures. (Refer to the transition from an "iron wire" frame to a "light wire" frame proposed by us).

3 - Scale compensation.
Scale compensation is particularly significant in the management of orthogonal views. The designer is used to have a visual-metric control of the drawing and uses well-defined scales.
The traditional method used for changing the scale consists in redefining the window and/or viewport.
The new method proposed by us consists in introducing a scale factor whiwh shifts the clipping limits into the window.

If a homogeneous coordinate clipping is used, the introduction of a homogeneous coordinate scale factor becomes a natural consequence.
The control of this parameter which we have called "clipping scale multiplier" (SW) is extremely simple.

If SW=1 the scale ratio stemming from the window/viewport transformation remains in force, if SW $\leq$ 1 we have an enlargement if SW $\geq$ 1 we have a decrease.

The clipping multiplier is a parameter that does not change the transformation matrices to which the frame refers and is therefore considered as being an attribute of the frame.

6. The software structure

In developing the prototype, programs were organized in three levels:

1 - Modules: basic libraries divided in libraries which are independent from the peripheral units and operating system and device-dependent libraries.
Wherever possible, we preferred not to use the basic libraries provided by the manufacturers since thay are usually very bulky, even for the management of a limited number of base functions.

2 - Protocols: programs managing the interacttvity and controls connected with a well-defined parameter set.

3 - procedures: protocol sets used for solving a particular application problem.

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Education and Training in CAD

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ABSTRACT

The teaching of computer-aided design in schools of architecture raises a number of educational problems. Some of these difficulties are reviewed and a postgraduate course in computer-aided building design, developed to meet some of the requirements identified, is described.

1. Introduction

It may be considered that there is sufficient debate about what constitutes the basic body of architectural knowledge to be imparted to students at schools of architecture without introducing further contention by adding another subject to the already overloaded curriculum. However, specialising in computing (in all fields) is now a relatively fashionable pastime, and its importance to architectural practice is likely to increase rather than diminish. All students should, therefore, be given the opportunity of developing some familiarity with the computer during their architectural education. Nevertheless, Schools of Architecture are still in the business of developing architects, and it should only be after the student has become an architect that, if appropriate, one could go on to develop a computer specialism.

2. Some problems

The additional load placed on the undergraduate curriculum is one of the most crucial factors affecting the teaching of CAAD. The volume of information related to architectural education has incresed to such an extent that it is no longer realistic to expect that it can all be covered to the same depth in the course of the normal undergraduate training. Different schools lay emphasis on different parts of the curriculum, but, unfortunately, these differences are not readily perceived by the prospective students. All schools, therefore, to a greater or lesser degree, attempt to cover everything they can, and concentrate on specific areas according to their different educational aims or, more pragmatically, the strengths and interests of their staff members. Given (in Britain at any rate) the recent cutbacks in education spending the specialist skills of the reduced staffs of many schools tends to distort the educational balance even further.

To find the time and the personnel to teach the emerging subject of CAD is a serious enough problem in many schools, even without considering the more fundamental educational issues involved. These issues may be broadly summarised in the philosophical question 'Are we promoting CAD education or architectural education using CAD?' Put the other way around, are students in schools of architecture learning how to use the computer in design, rather than how to design using the computer.

A number of factors may contribute to this state of affairs. The software available for use in teaching in schools of architecture is often limited to software developed within the school itself. Therefore its use is often for pragmatic rather than theoretical, educational, reasons. Very rarely is software available which was specifically developed to meet education requirements: and the needs of education (as distinct from practice) are such that the use of "professional software" developed commercially for sale to architectural practices would be no better educationally.

This gap between education and practice is particularly sharply defined in CAD. Such software as is used in education tends to be for design analysis and ad hoc problem solving, whereas the software used in practice is mainly for production information and management. Production information plays a minimal part in most school courses, but can account for some 80% of a practices costs. Again, management is a relatively minor element of most courses, but, with the software industry able to sell accounting packages to a wider market than just architects, the software is relatively cheap to acquire and, therefore, often cost-effective for the user.

It is not even really possible to "train" students in the operation of the professional systems, as distinct from "educating" them in the underlying principles. There are a wide variety of draughting systems available, none of them easily within the available budget of a school of architecture, but all so different in their operation that a 'training' on one is of very little use should one need to use a different system. Even the terminology varies. Different systems use different terms to describe similar (or, in some cases, identical) features. Or, more confusingly, the same term to describe different features. As a trivial example, what an architect would call a standard detail some systems call "components", whilst another divides them into "objects and blocks". What is important in all cases is not the mechanics of operation but the implications on the structuring of drawings and the requirements for the architect to become a "database manager".

Further considerations reinforce this gap between education and practice. Most programs currently available suffer from user interfaces which are not easy for the casual or intermittent user to master; from onerous data preparation requirements; and concentration on specific (limited) aspects of design. These limitations can all be tolerated in practice because of the economic returns, but in education there is neither the time or the facilities to overcome the problems. The result is that rather than computer programs being adapted to suit educational requirements courses are adapted to suit the available programs.

3. Some responses

All of these considerations make the task of integrating CAD education into the undergraduate curriculum increasingly difficult. At the moment CAAD education tends to be a special "block" inserted into the normal curriculum, rather than a natural part of the subject as a whole. "Computer-aided design" is taught as distinct from just "design" (which may or may not make use of computers). A typical course structure is described by Maver and Schijf [1]. The course consists of five modules as follows:

1. Exposition - the concepts underlying CAAD, a survey of the state of the art, and demonstrations.

2. Preparation - practical experience using a range of programs and discussion of their form, content and interfaces.

3. Application - using one or more programs in a studio design project.

4. Instruction - acquiring programming skills and knowledge of hardware and software systems.

5. Development - specifying, implementing and maintaining hardware and software systems.

Modules 1,2 and 3 are intended to give students a general awareness of CAD; units 4 and 5 are used for students wishing to develop special CAD expertise.

At the moment it is difficult to see any viable alternative to this pattern. The staff and facilities just do not exist, yet the value of much of the enterprise may still be questioned. The software used in the central application modules places severe restructions on the permissable design forms; there are also difficulties associated with data input, and limitations on allowable building types and the data measured. The process of use is time consuming and frustrating. The benefits of its use are questionable. Students see only some of the worst aspects of CAD (not necessarily a bad thing) but learn nothing of the real potential. It is also quite remote from CAD use in practice. Until better software, written especially for teaching use, is available it is difficult to see this pattern of teaching improving.

The immediately available alternative is to make more use of quick, easy to use programs, made available on small computers, readily accessible in the design studios, and look at the complimentary 'professional' computing by visits to offices using computers or video instruction films. It is important that the current generation of students are made aware of computing methods and applications for it is sure to figure at some time during their professional career. However the long term solution to the problem lies in training more CAD specialists - both to become a more critical, demanding and selective client for commercial CAD systems, but also to provide the manpower to develop the next generation of software (or perhaps the first generation of specialist CAD teaching software) which is so desperately needed. This, obviously, cannot be done within the already overcrowded undergraduate course. The only answer is a specialist post-graduate course which would provide young architects wishing to specialise, or older architects wishing to retrain, with the opportunity to develop specialist CAD skills and then participate themselves in computer aided design, research and teaching; or act as interfaces between designers and computing specialists; or return to practice with the expertise to exploit the opportunities offered by computers and computing.

The remainder of this paper describes a one year, full time, postgraduate course in the techniques of computer-aided building design which aims to provide graduates from an architectural, engineering, surveying or other building related background with those particular CAD skills.

4. The Strathclyde MSc (CABD)

The course contains three main themes - Design Methods, Computing Methods and CABD Applications. The general framework is that the course consists of two thirds formal course work and one third dissertation. The course units themselves follow a two thirds to one third split between lectures and assignments specifically related to the project unit. The students are also required to write an essay over each of the Christmas and Easter 'vacations'.

The students are assessed upon their performance in the assignments and essays (approximately half of the total mark) and a formal dissertation which is written after the completion of the course work at Easter for submission in August. There are no formal examinations as such. The course units are described in Appendix 1. The type of work undertaken in the course is indicated by the following range of projects and dissertations, selected from the work done in the previous academic year.

5. Projects

Design Methods Projects - application of a number of different techniques and critique of ease of use, effectiveness as design aid, etc.

Appraisal Project - use of program and critical appraisal of user interface, data required v. results obtained.

Computing Project - analysis of simple problem (eg checking of stair case design against building regulations), structured English formulation, iterative refinement, coding.

Subsystem Evaluation Project - critical use of program for detailed design evaluation - eg dynamic thermal simulation.

User Interface Project - development of an improved user interface for an existing program, or specification for a user interface module.

Visual Impact Project - actual project preparing computer-generated photomontages or theoretical study of, eg colour variation under different types of lighting.

6. Dissertations

Appraisal in CABD - a critical analysis of available software; a discussion of techniques to meet the main criticism; the development of a system of "fuzzy appraisal".

User Interface for Integrated CAAD Systems - analysis of 3-D modelling systems and use of raster-op bit-map graphics techniques to develop a sophisticated interface.

The Computer Based Building Model - Development of a specification for a full 3-D modelling system.

Computer Aided Maintenance and Management - proposals for an automated information system for maintenance engineers.

How the Use of Computing Draughting Systems by Architectural Practices is Effecting the Design Process.

Computer Graphics Output in Architectural Practice: how architects using computer draughting systems still develop their own identifiable "house-style".

7. Resource implementation

A number of different types of resources are needed to support a course of this type. The human resources are drawn from the ABACUS research unit in the Department of Architecture, whose staff include personnel with backgrounds in architecture, engineering, mathematics, operations research and computer science. These resources are extended by research students in the department acting as part time tutors; by visitors to the unit; and by visits to local offices already using computers.

The physical resources required include a wide range of computing hardware and software. The course provides computing experience across a range of hardware from desktop microcomputers through minicomputers to large time-sharing mainframes. A range of terminal equipment from simple alphanumeric terminals through storage tube and raster scan graphics screens to sophisticated colour raster graphics screens is available. Other peripherals inlcude digitisers and plotters,. various hardcopy devices and video interface equipment. The software available includes specially written teaching packages, a wide range of application programs, and a wide range of system software. Sutdnets are encouraged to invesitgate different high-level languages and operating systems.

Beyond these obvious physical requirements are two other important resources. One is the presence of an active CAD research unit which adds to the authority of the course and draws visiting specialists to the Department. Following upon the presence of the research unit is the availability of a good CAD library. The specialist books, conference proceedings and journals required to support a course of this nature are not always available in most schools of architecture.

8. Conclusion

The volume of information related to architectural education has increased to such an extent that it is no longer realistic to expect that it can all be covered to the same depth in the course of the normal undergraduate training. Similarly, the rate of change in theory, techniques and technology is such that the knowledge base acquired cannot be expected to serve the graduate architect throughout his professional life.

The field of computer-aided architectural design is an extreme example of both the extension of the field of study and the fallibility of outdated information. Furthermore, many architects in practice have had little or no contact with computers in their professional education.

The MSc course is designed to meet this need for postgraduate education in CAD. To the extent that the students so far have been a mix of younger architects wishing to specialise and older ones wishing to retrain, the course appears to be succeeding. To the further extent that two recent graduates have gone to teach in schools of architecture, another has joined a CAD system vendor, and others have done into architectural practice, the quality of architectural CAD, criticised at the beginning of the paper, may slowly begin to be improved.

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1. Maver, T W and Schijf, R, '"International Implementation of a CAAD Project in Schools of Architecture". Bulletin of Computer Aided Architectural Design, No 47, February 1983, pp3-16.

APPENDIX 1: MODULES OF THE MSc (CABD)

APPLICATIONS 1

Computational Methods in Building Design

An introduction to the application of computer methods in architecture and building science. Covers the following areas to provide information on the basic tools available to handle typical problems.

(a) general introduction to computer systems; (b) brief analysis;
(c) generation of design proposals; (d) appraisal of design proposals;
(e) building costing; (f) building structures; (g) energy usage;
(h) building services; (i) daylight evaluation; (j) artificial lighting;
(k) acoustics; (l) solar energy; (m) visualisation of design proposals;
(n) visual impact analysis; (o) office management applications;
(p) information retrieval; (q) specifications and bills of quanitities;
(r) computer draughting. Followed by 1 week project.

APPLICATIONS 2

Computer Applications in Architecture

Identifies those areas in architecture qhere, (i) significant use of computer techniques has been made, and (ii) future applications areas. Topics covered included the use of computers in the following areas.

(a) predesign decisions - ecomonic studies, feasibility studies, brief development; (b) layout planning - representation of architectural spaces, representations of objectives and constraints, characteristics of different solution techniques, MAGIC; (c) integrated design appraisal - representation, measurement, evaluation, GOAL; (d) building subsystems appraisal - energy, lighting, visual aspects, ESP BIBLE/VISTA; (e) specifications and bills of quantities - line and paragraph techniques, master bill techniques;
(f) office management techniques - job and timesheet accounting, wordprocessing, CPM and forecasting; (g) automated draughting systems - devices and techniques, commercially availabel systems, integrated systems; (h) current research - ABACUS, elsewhere.

APPLICATIONS 3

Computer Applications in Visual Analysis and Modelling

The use of advanced computer graphics techniques in assessing the visual impact of proposed engineering and architectural developments.

(a) current visual modelling techniques; (b) evaluation of traditional methods of visual analysis; (c) computer potential in visual impact analysis;
(d) photogrammetic techniques; (e) computer generated pictures and montages;
(f) issues of accuracy. Following by one week project.

APPLICATIONS 4

Computer Applications in Building Subsystem Evaluation

An advanced examination of computer applications in the detailed evaluation of building subsystem performance.

(a) detailed modelling of building interiors; (b) simulation of interior lighting effects; (c) colour rendering of different artificial lighting schemes;
(d) lighting systems; (e) acoustics evaluation; (f) energy modelling and energy resources; (g) numerical simular energy models - harmonic, response function, finite difference, computational methdos; (h) numerical simulation technqieus; (i) climatological data; (j) plant modelling; (k) examples using the ESP simulation system. Followed by one week project.

DESIGN METHODS 1

Introduction to Systems Theory and Design Methodology

An introduction to a systems approach to design, together with a number of formalised design methods.

(a) traditional methods of design; (b) the concepts of systems theory and its relevance to building design; (c) scientific mehtods; (d) new attitudes towards design - the concept of modelling; (e) formal design methods; (f) statistical design methods; (g) human science techniques; (h) problem solving techniques; (i) creative techniques; (j) development of design methodologies; (k) new design processes; (l) computer aided design. Followed by one week project.

DESIGN METHODS 2

Models in Building Design

To develop an appreciation of the role of architectural and environmental sciences in the overall field of design practice and education.

(a) new forms of building - problems posed by these new forms, growth of scientific methods of analysis, use of physical and mathematical models; (b) social changes - effects of legislation on build forms, impact of computing on design, changing role of building designers, the energy crises; (c) summary of role of designer in practice and society, and relevance of systems approach.

DESIGN METHODS 3

Brief Analysis and Layout Planning

An exploration of the computational aspects of the fundamental architectural planning problem.

(a) types of data - activity data analysis, quantitative, qualitative and dichotmous data, representations of data; (b) analysis of data - cluster analysis, multidimensional scaling; (c) relationship between brief analysis and layout planning/facilities planning; (d) representations of space - integer array, dimensionless vectors, point vector, graph theoretic; (e) representation of objectives and constraints - adjacencies, constraint graph, dimensionless formulations, fit problems; (f) solution procedures - generate and test, hill climbing, heuristic search, implicit enumeration, linear and nonlinear programming, artificial intelligence approaches; (g) layout planning programs - CRAFT, GSP, IMAGE, CORELAP, SPS. Followed by one week project/essay.

DESIGN METHODS 4

Operations Research Applications in Design

An introduction to the techniques of operations research applicable to design.

(a) applied graph theory; (b) probability theory; (c) probability distributions; (d) algebraic and differential equations; (e) combinatorial programming; (f) Markov chains; (g) simulation modelling; (h) regression and correlation; (i) hypothesis testing. Followed by one week project/essay.

COMPUTING METHODS 1

Introduction to computing.

An introduction to computer hardware and software.

(a) general concepts - analogue devices, digital computing; (b) computer hardware - mainframes, minis and micros, peripherals; (c) using computers - terminal connection, running a program; (d) software engineering - the concept of software engineering, software design methodologies, modularisation, portability of software; (e) software - systems software, machine independent operating systems, software libraries, software tools, applications software; (f) programming languages - review of different languages and their applications, FORTRAN language, writing FORTRAN programs, standards. Followed by project.

COMPUTING METHODS 2

Advanced Introduction to Computing

An opportunity to study advanced computing concepts and their application in architectural computing.

(a) advanced FORTRAN - file handling, data structures, interactive computing, graphics; (b) special problem-oriented languages - GLIDE, CECIL; (c) software tools - graphics libraries, utility libraries, I/O conventions.

COMPUTING METHODS 3

Mathematical Methods

To thoroughly acquaint students with the mathematical techniques necessary in computer graphics applications.

(a) Matrix methods - matrix algebra, diagonal matrices, submatrices, determinants, etc, linear equations, mappings, projections, perspectives, etc, matrix inversion, tridiagonalisation, computer solutions and further applications in computer graphics, numerical analysis - accuracy and error propagation; (b) graph theory - introduction to graphs and networks, planar/nonplanar graphs, trees and directed graphs, computer representations, applications in data storage, etc.

COMPUTING METHODS 4

Computer Graphics in Design

Advanced consideration of computer graphics devices and techniques.

(a) display devices; (b) display files; (c) transformations; (d) clipping and windowing; (e) interactive graphics techniques; (f) graphical input techniques; (g) colour graphics techniques; (h) graphics systems; (i) graphics languages; (j) general applications; (k) special applications - video montage and mixing.

COMPUTING METHODS 5

Microcomputer Applications

A more detailed examination of microcomputer hardware and software. Opportunity for hands-on experience with a wide range of micro-computers is provided in association with the Microelectronics Education Development Centre.

(a) central processor units; (b) memory devices; (c) mass storage; (d) input and output peripherals; (e) system programs; (f) application programs.

COMPUTING METHODS 6

Databases and Interfaces

A detailed discussion of information and databases in design applications and a further consideration of aspects of the man-machine interface.

Databases - (a) shape descriptions; (b) topology and geometry; (c) component libraries; (d) conceptual models; (e) logical models; (f) physical models; (g) data analysis; (h) functional analysis; Interfaces - (i) conceptual design; (j) semantic design; (k) syntactic design; (l) lexical design; (m) user interface models; (n) user interface management systems.

Case Studies in Computer-Aided Visual Impact Analysis

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1. Introduction

The aesthetic effect of any new development on its surroundings, whether a new shop in an historic urban setting, or a powerstation in unspoilt countryside, is always a contentious issue. This is not solely due to the merits (or otherwise) of the proposed development, but rather the underdeveloped state of objective visual appraisal. The accuracy and realism of traditional visual assessment methods are known to be questionable and new techniques which can clearly present visual evidences in sufficient detail and with known levels of accuracy are only slowly replacing them.

This paper describes the use of two computer-based methods of predicting the visual impact of buildings (or other constructions) on their surroundings. The programs BIBLE (Buildings with Invisible Back Lines Eliminated) and VISTA (Visual Impact Simulation, Technical Aid) offer the designer a two stage approach to visualisation. The first stage is the production of wire-line perspective views; these may be perfectly adequate where issues of visibility predominate or where the object has a skeletal structure (eg electricity pylons). The program output may be used directly in a photomontage or as an accurate starting point from which a perspective artist may develop a presentation drawing. The second level is the production of coloured, textured and lit perspectives which may be used where issues of visual quality predominate. These pictures may also be photomontaged.

2. The program BIBLE

BIBLE is a perspective line drawing program the user interface of which (Figure 1) is designed to be as simple to use as possible. This is mainly achieved by four features:

a) Fail-soft design: any invalid or wrong input produces an English-language error message, apologising for the program's inability to understand the input provided and explaining what sort of input was expected, or what options were available to the user at that point.

b) Graphical specification of view point. This allows the user to point on a displayed plan view to a place in the vicinity of the building(s) and, in effect, ask 'What does it look like from here?'

c) Use of default parameters: all the view control parameters have default values computed by the program for each data set as it is read in. Thus it is possible to read the data file and immediately get a meaningful picture.

d) A command menu on the screen gives the user a visible reminder of what he can do without verbose prompts, and more detailed information can be obtained by selecting the HELP command.

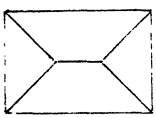
Hidden lines may be removed (which is the default), drawn dashed, or left in. The projection may be perspective (by default), partially perspective (parallel verticals, parallel horizontals), or orthogonal. Output may be to a display file, to the terminal screen or to a plotter with the drawing produced to A1, A2, A3 or A4 size; output devices may be changed between pictures.

A major facility offered by the program is that of producing views which can be automatically superimposed onto site photographs. The user specifies the camera position, the focus point, the focal length of the camera lens and the enlargement of the photographic print relative to the size of the negative. The resulting view is then correctly scaled, positioned and proportioned for the photomontage.

```
PICK: ?HELP TO LIST COMMAND OPTIONS AVAILABLE
  BYEBYE TO EXIT
  /INPUT TO TYPE IN NUMERICAL VALUES OF E F OR M
  EYEP   TO PICK THE EYE POINT WITH CURSOR
  FOCUSP TO PICK THE FOCUS POINT
  MIDP   TO PICK THE PICTURE MID-POINT
  HIDDEN TO REMOVE HIDDEN LINES
  DASHED TO DRAW THEM DASHED
  VISIBL TO DRAW THEM SOLID
  LENSFL TO SPECIFY LENS FOCAL LENGTH (IN MM.)
  %ENLRG TO SPECIFY ENLARGEMENT FACTOR (NEG. TO PRINT)
  ANGLEV TO SPECIFY VIEWCONE ANGLE (DEGREES)
    (NEGATIVE FOR BIGGEST PICTURE THAT WILL FIT)
```

BIBLE

?HELP	%ENLRG
/INPUT	ANGLEV
EYEP	4PAVER
FOCUSP	3PAHOR
MIDP	2PERSP
HIDDEN	1ORTHO
DASHED	TYPALL
VISIBL	INPALL
SCREEN	CALCMP
BYEBYE	PLOTL
LENSFL	NEWFIL
	OUTFIL



```
  1ORTHO TO SELECT ORTHOGONAL PROJECTION
  2PERSP TO SELECT PERSPECTIVE PROJECTION
  3PAHOR TO SELECT PARALLEL PROJ ONTO HORIZ.PLANE
  4PAVER TO SELECT PARALLEL PROJ ONTO VERT PLANE
  TYPALL TO TYPE OUT ALL VIEW PARAMETERS
  INPALL TO TYPE IN ALL VIEW PARAMETERS
  SCREEN TO DRAW THE PICTURE ON THE SCREEN
  CALCMP TO PLOT IT ON CALCOMP PLOTTER
  PLOTL  TO DRAW THE PICTURE ON LOCAL TEK PLOTTER
  OUTFIL TO FILE A PICTURE IN A BIBLE VIEWFILE
  NEWFIL TO SELECT A NEW INPUT GEOMETRY FILE.
```

Figure 1

Screen hardcopy showing BIBLE menu, response to HELP command, and small scale plan of building ready for user to select viewing point (or focus point, etc)

3. The program VISTA

VISTA is a colour perspective package with hidden surface elimination; it may be used to model any artifact composed of planar surfaces (Fox, 1). Although wireline perspectives, as produced by BIBLE, can be valuable aids to visualisation, they remain indicative and lack solidity. The use of colour to fill the surfaces improves the three dimensional impression of the drawing, especially if the colours are modified according to the light falling on them and shadows generated. A detailed description of VISTA may be found in Stearn (2). Basically the VISTA database contains a hierarchically structured definition of the geometry of the model. This definition is similar to the BIBLE geometry definition, being composed of Bodies which contain planar faces, but VISTA allows another additional level of detail to be associated with each face. These extra elements are known as Tiles, and may be used to model areas of different colour, or features such as windows and doors, on the face of a building. Because of the close relationship between the geometric data required by both BIBLE and VISTA, the VISTA database is created from a BIBLE data file by running the interface program BIBVIS. This has a number of advantages - a large number of data sets already exist in BIBLE format; programs for creating BIBLE geometry already exist; if the geometry exists in BIBLE format then it can be run by both programs. In addition to the geometrical description of the model the VISTA database also contains the colour details for each Body, Face and Tile in the model.

The core of the VISTA package is the VIEW module. This performs the perspective transformations, the hidden surface elimination and the colour rendering. It takes as input the description of the model as defined by the VISTA database and the required viewing and lighting parameters. The viewing parameters consist of the type of view required (bird's eye, camera, etc) and the eye and focus positions. The lighting parameters specify the position and spectrum of any light sources (in RGB) and whether any shadow studies are to be retrieved. The lighting model in VISTA allows the used to model the ambient, diffuse and specular components of any light source, and also to vary the ratio of ambient to direct light available from that source. The output picture is written to a display file rather than directly to a colour output device. This has several advantages, the most important of which is that the VIEW module can be totally device independent.

4. Case studies

The use of the programs briefly described above allow a thorough visual investigation of design proposals to be made. Early use of the software, together with a more general description of visual impact analysis, is described in Bridges (3).

Further use in live projects has indicated new directions for program improvement and stimulated continuous revision and reappraisal of program capabilities.

The issue of accuracy is obviously fundamental. This has been rigorously investigated (Purdie, 4) and a number of features, not always included in CAD perspective packages, have been incorporated in the software. For example, in long range visualisation (over 3 kilometres) the curvature of the earth and light refraction can affect the position of objects as seen by an observer. Similarly optical and other camera distortions can cause a mismatch in computer based photomontaging. The software now takes account of these points and the accuracy of the photomontaging process using BIBLE has been firmly established both theoretically and practically.

Unfortunately the available data is often not of the same standard or accuracy as the program. Computational techniques have therefore been developed to determine unknown or check dubious data. For example in the case of the design of a second power station on the Hong Kong mainland at Castle Peak (architects

Robert Matthew Johnson-Marshall) the viewpoints of a number of the site photographs were unknown, these photographs having been taken from a ferry or a helicopter. The building geometry was assembled and prepared for viewing by the program BIBLE. The onshore photomontages were drawn. To locate the viewpoint co-ordinates of the offshore and aerial photographs a program was devised to iteratively search back to find the correct observer position. This procedure was based on a triangulation method with two known objects in the photographs and the computer views being fixed and the viewpoint acting as the variable. Finally, the accurate wire line perspectives and the colour site photographs formed the basis of a set of finished colour montages produced by a perspective artist. The level of detail included was such that quite elaborate drawings of the power station itself could be produced (Figure 2).

A different application is the use of computer-generated pictures during the course of the design of the building. An example of this type was undertaken in the context of the evaluation of design proposals for the Z.A.C. du Moulin à Vent at Cergy-Pontoise new town. Architects Claux-Pesso-Raoust in association with the urban designers Warnier, Gaillard, Jarouen wished to simulate pedestrian views along the main footpaths; to draw perspective views of the proposed design from critical viewpoints and investigate colour rendering and shadows cast at different times of the year. As the purpose of the exercise was to investigate massing and shadowing no facade details were included.

Another, complimentary, visualisation has also been undertaken with Claux-Pesso-Raoust. In this case (at Dreux new town) on a smaller site a more detailed modelling was undertaken.

5. Conclusion

Two serious areas of concern still remain.

i) Data inaccuracies. Incorrect reportage of survey data identifying viewpoint and control point information causes delays and necessitates rechecking and reprocessing the computer views.

ii) Overlaying. The difficulty in effecting a realistic colour montage when views of the development are interrupted by foreground features, still remains unresolved unless time consuming hand creafted methods or sophisticated video mixing techniques are used. This runs against the idea of speedy, cheap computer based visualisation.

The theoretical issues of accuracy have already been mentioned, and, ultimately, the validity and usefulness of a modelling aid will be measured against its ability to predict reality. Fortunately this is a fairly easy criteria to validate. By the simple expedient of drawing an existing building computer predictions may be compared directly with reality (or montages compared with photographs of reality). This retrospective visual appraisal was undertaken on the Architecture Building at the University of Strathclyde.
At this level of detail difficulties arise in the convincing modelling of landscape and the simulation of window glass and other reflective materials.

A number of general problems still beset these techniques - not least the difficulty of accurate colour copying and reproduction. Maintaining the correct colour balance and quality of hardcopy reproduction from graphics terminals has consistently proved to be a stumbling block in the presentation of accurate visual evidence, especially when building surface colours and textures are under examination. Significant improvements in the copying and reproduction of colour computer graphics for visualisation in architectural design are required if the benefits of building detailed simulation models are to be realised.

Many techniques for visual assessment are only initiated in the later detailed stages of design work. In contrast, there is a greater need for methods and models to be developed and applied at the earlier outline stages of design, where the major visual design decisions are normally taken. Computer-based models seem best structured for continuous application throughout design from inception to completion, and beyond in terms of visual resource management in future planning and landscaping.

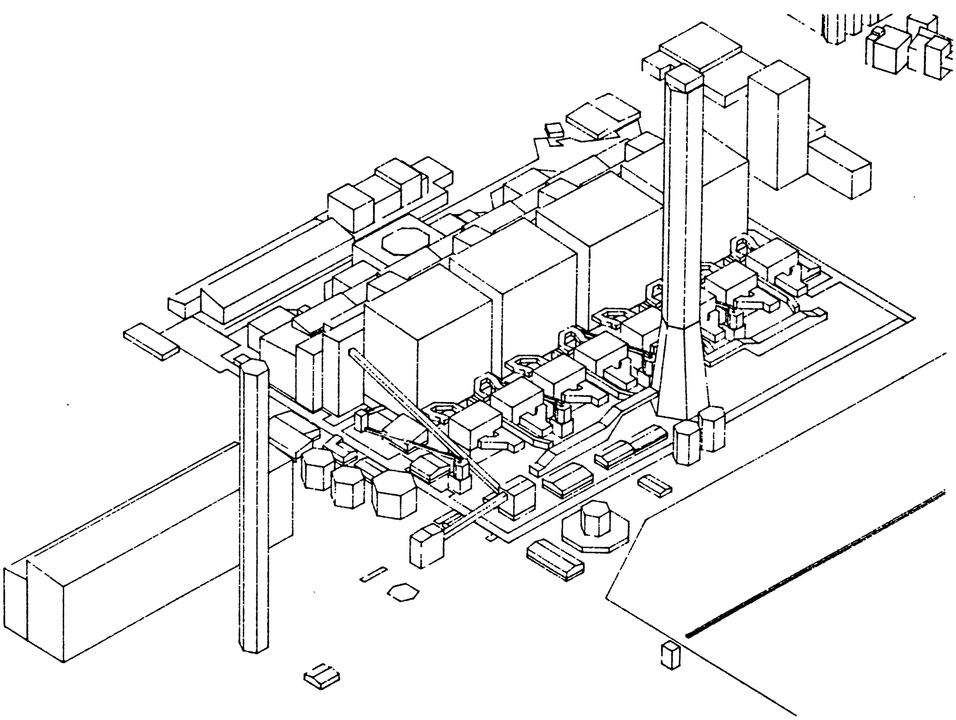


Figure 2
BIBLE perspective view of Castle Peak power station

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6. Acknowledgements

Many people at ABACUS have contributed to this area of computer application, but the examples described would be far less convincing without the intellectual efforts of Cameron Purdie and the computer programming skills of Donald Stearn.

An Integrated Approach to the Use of Computers in Construction: The Nordic Effort

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ABSTRACT

In all the Nordic countries a number of research, development and standardization projects have been started to aid design and construction firms which are introducing CAD-systems. One of the principal aims of the projects is to pave the way for integrated computer-aided building design, including interfaces to CAM systems. In this paper some of the projects are described.

1. Introduction

The aim of this paper is to give the reader a brief survey of how the construction industries in the four major Nordic countries (Denmark, Finland, Norway, Sweden) are trying to cope with the demands posed by the introduction of computers, and more specifically with the difficult subject of integrated computer-aided building design. The paper deals with research, pilot projects, software development and standardization. It is based on a survey done for the Nordic Council of Ministers by a working group for information technology appointed by the Cooperation Organization of the Nordic Building Research Institutes[1]. The survey constituted the first part of a project aiming at the definition of a strategy for joint Nordic research, development and standardization projects.

2. The construction industry and information technology

Construction has until recently been an activity guided more by tradition than conscious development of new methods. The research and development effort of construction firms has mainly been devoted to development of new materials and products and the process of design and construction has received very little attention. The share of R & D of the total output of the construction industry has been very little compared to most other industries.

The new possibilities offered by information technology have lately focused a lot of attention on the improvement of working methods in the construction industry.

Before the 1980-ies almost the only users of computers in the construction industry were engineers doing complicated structural calculations.

During the last few years the scene has changed radically. There is no need in this report to go into the details of the rapid development of computing.

Due to the large number of highly specialized small firms which constitute the construction industry it has been affected by this revolution slightly later than some other industries. But today even a one-man consultancy can afford to buy its own computer and can find efficient uses for it.

In many respects the construction industry faces unique problems in the implementation of information technology. It is a highly fragmented industry were the need for data exchange between different co-operating firms is a crucial factor. It also handles large amounts of graphical information, which necessitates complicated software and expensive peripheral equipment. It's product is usually unique and changes from one project to another. It is thus not possible to use anywhere near as much time and money for the planning of a building as for the planning of a car or an airplane.

3. The situation in the Nordic Countries

In the use of computers in construction the Nordic countries have been implementing a technology which has been developed abroad and which to a large extent originally has been intended for other industries. Most CAD-systems, for instance, originate from the USA or the United Kingdom. In spite of the term turn-key systems most of these systems are by no means efficient operational tools at the moment of their installation. Design firms which have purchased CAD-systems have found that training, definition of internal procedures and standards, creation of symbol libraries etc. may require 1-2 years. The future use of micro computers on building sites, possibly connected to the building contractor's central computer, will create even greater organizational problems. These are problems which the computer specialists cannot solve, the construction industry must solve them themselves.

Furthermore these problems are closely related to the organization and traditions of the construction industries of specific countries. Solutions cannot thus be imported directly from abroad.

The need for industry-wide cooperation has been recognized in all the Nordic countries but the solutions differ. In Denmark a Society for Computer Applications in the Construction Industry was founded under the auspices of the Danish Academy for the Technical Sciences in 1984. The primary aims of the society are to collect and distribute information and to initiate research and development projects. A CAD/CAM centre for the construction industry has also been founded in Denmark. Its aims are to provide basic information to firms contemplating purchase of equipment and to provide basic training. It caters mainly to contractors and the construction materials industry.

In Finland the discussion has centered on how to achieve integration between the CAD systems of different designers and between the CAD systems of the designers on one hand and the tendering and production planning systems of contractors on the other. A large co-ordinated research and development program has been seen as a solution to this problem. In order to initiate and monitor the program all the major professional organizations have together founded the Construction Industry Council for CAD in Building (RACAD) in 1983. RACAD has participated in the initiation of a number of projects, but it hasn't managed to finance the 2 M USD-project originally intended. A research project where the information flows in the design process are studied is, however, currently starting.

In Norway impartial information and advice to construction firms buying hard- and software has been given high priority. A committee appointed by the Norwegian Technical and Natural Science Research Board (NTNF) proposed a 4 milj. USD research and development program in 1982[3]. Only a few projects have been started[4]. One of these was the creation of an information centre for computers in construction (BA-DATA), which currently works in connection with the Norwegian Building Research Institute.

Of the Nordic countries Sweden is possibly the most advanced in the utilization of information technology in construction. Research has also been more intensive in Sweden than in the other countries, possibly because construction related R & D is supported almost to 100 % by its own fund, the Swedish Council for Building Research (BFR). Together with the Institute for Building Standardization (BST) the Council for Building Research has founded a special CAD-committee which co-ordinates and initiates research, organizes the exchange of information etc.

In addition to the organizations already mentioned the architects' organizations in all the four countries have more or less directly founded CAD-societies. The building information services are also currently developing computerized database systems.

4. The design process and CAD

4.1. Design as a research topic

One curious impact of the growing use of computer-aided design is a renewed interest in the design process itself. On one hand the use of computers poses demands for more rigorous procedures concerning formatting of information, data exchange etc. On the other hand computers offer new possibilities for improvements in the design process, for instance visualizations, functional simulations and cost estimation.

Studies of the building design process range from rather theoretical studies concerning the basic cognitive process involved ("how do designers design") to practical systems analysis of the information flows in the design process. The latter type of studies are in fact a prerequisite for constructing large integrated computer-aided design systems.

4.2. A system analysis of design information flows

One of the principal aims of the Finnish Construction Industry Council for CAD in Building (RACAD) has since the start been to initiate research and standardization which would provide a basis for integrated computer aided design. These efforts have resulted in the formulation of the RATAS-project.

The aim of the RATAS-project is to study the current design process assess the scope for its improvement, and to make a systems analysis on how the process should look like in the future. The study concentrates on the exchange of information between the different participants in the design process (client, architect, structural, mechanical and electrical engineer, contractor, subcontractors). The documents, which are exchanged between different participants, ie. drawings, specifications, calculations, will be identified, and their information content will be defined in sufficient detail to provide a basis for the programming of integrated CAD software. In principle the project is independent of the use of CAD in design work, but it is hoped that the main effects of its results will be better compatibility between systems developed for and by Finnish design firms and contractors. Systems development can in this context be the tailoring of foreign

CAD-systems to the needs of Finish firms. The project has started in the summer of 1985 and will be finished by the end of 1986. The resulting recommendation will be tried out in real design projects early in 1987.

4.3. The Bollnas pilot study

A lot of what has been said in the past few years of the effects of CAD on the design process has been based on theoretical speculation or experiences from other industries. None of the hypothesis concerning the productivity increase in draughting work, the shift in emphasis of design work from routine documentation to creative evaluation of alternatives, the usefulness of 3-D modelling as a means for reducing errors etc. have been empirically verified. It has also become increasingly clear that the main difficulty in implementing computer systems in the construction industry is that the implementation necessitates development of the design and production process itself. The only way to find answers to such questions is through systematic observation during design projects where CAD-systems are used. One such project has already been carried out in Sweden and similar projects have been started in both Finland and Denmark.

For the design of an office building in Bollnäs the Swedish Board of Public Buildings decided to use a team of design firms using the same CAD-system (MEDUSA) and to collect the experiences is a systematic way[5]. The study was carried out by a team of independent researchers. The building is a medium-sized office building offering a fair amount of repetitive details.

The emphasis in the study was on the identification of problems which occurred during the design process. One of the purposes was to provide empirical material for decisions concerning future research, development and standardization efforts. The Board of Public Building also wanted to evaluate the advantages and disadvantages of using CAD in its own projects in the future. A crucial question was weather CAD provides a better means of co-ordination in the design process compared to traditional means, as well as a better means of communication between designers and contractors. The project was financed jointly by the Council for Building Research and the Board of Public Buildings.

The results of the study should be interpreted with caution. In the project CAD was used for the first time by most of the designers. Any conclusions therefore relate to the use of CAD in the middle of a learning process and not in a stable, everyday environment. Some interesting observations were:

- A standard for the use of layers in integrated projects would be useful. Part of the layers could be allocated to the different designers for their internal use. The contents of those layers which all designers would have access to should be standardized.
- In the long term it would be useful if menus and keyboards could be standardized. Due to the way the construction industry operates design firms may have to use different CAD-systems in different projects. It would be very helpful if for instance application specific symbol menus were standardized.
- The potential of CAD systems for detecting design faults such as overlapping structures and installations, were not fully utilized in the project. One way of handling the problem is to use the layering facility to produce simplified drawings containing only the relevant information, which in turn makes manual checking by looking at the drawings more simple.
- The routines for defining authorized drawings, originals and revisions should be further developed as a part of the system software. The

design process must be planned and monitored more carefully if CAD is used
- Training of the personnel will become a crucial and time consuming factor in the implementation of computer aided design.
- It is not advisable to use a CAD-system of the traditional turnkey type for the early, creative phases of design. Obviously some tasks, such as drawing perspectives can be done, but overall the technology has to develope.
- Certain draughting symbols create problems for CAD-systems. Some revision is needed of existing standards. This concerns especially the electrical designers who use a lot of symbols.

The Bollnäs project has been followed up by a study concerning the benefits and disadvantages of CAD-produced documents in the construction process. Preliminary results indicate that the overall effect is positive.

4.4. Other pilot studies

Inspired by the Bollnäs study the Finnish Board of Public Buildings together with the Technical Research Centre of Finland have decided to carry out a similar study on the use of CAD in the design of a new laboratory for the Technical Research Centre[6]. The actual design of the building has started in April 1985 and will be finished by August 1986.

The framework of the Finnish study differs somewhat from the Bollnäs project. The architect and the mechanical designer will use a PRIME minicomputer and the MEDUSA CAD-system. The structural and electrical designers are using a different system, DOGS, which runs on a VAX-computer in a CAD service center. Files produced using MEDUSA will periodically be transferred to the central project database on the VAX by special purpose software for the conversion of MEDUSA files to the DOGS format. The communication between different CAD-systems in the same integrated project will thus be one interesting topic to be studied.

The project also differs from the Swedish project from a methodological point of view. The research team will use their own graphics workstation and standard personal computers equipped with graphics terminal emulators to access the databases which the designers create. The researchers will thus at the same time find themselves in the position of the client of the future, who undoubtedly should be able to access the design under work in a similar fashion. The working patterns of the designers at the workstations will also be systematically followed. The aim is thus to provide statistical facts in addition to experiences collected through interviews. An interim report will be completed in the spring 1986. The final report is due at the end of 1986.

Two studies of the use of CAD in real design projects have started simultaneously in Denmark in the summer of 1985.
An extension to a laboratory for the Danish Post and Telegraph Board was designed using the INTERGRAPH system of a large engineering consultancy. The participating architectural practice rented a workstation which was connected to the main system. The design phase was completed in November 1985. A seminar will be arranged where the work done will be demonstrated and where the results of the study will be presented.

The project has received a grant from the Danish Council of Technology (Teknologistyrelsen). In contrast to the Swedish and the Finnish projects the grant will to a large extent be used to cover the additional expense for using CAD in the project as compared to traditional methods. The report will be written by the designers themselves. The emphasis is more on demonstrating the use of CAD in a real project than on actually studying the effects thoroughly. The seminar which will follow the actual design work is thus an important part of the project.

The second Danish demonstration project, which also receives support from the Council of Technology, is geared towards the use of cheap microbased systems in building design. The idea is to study how micro-based software could be used in real design projects, and how the exchange of information between the participating designers should be organized in order to enhance the efficiency of computer use. The experiment will be carried out in conjunction with two real design projects. The first of these is the design of an extension to a University library. In this project both 2D and 3D work will be evaluated. The second project concerns the design of prefabricated staircases and bathrooms. In this project the establishment of standard libraries and the interplay between design firms and producers is in focus.

5. Development of integrated CAD software

5.1. Strategies towards integrated CAD

During the very short time that CAD-programs have been used in design practices in the Nordic Countries it has become clear, that the step from a commercially sold software product to a design aid which is well integrated into the everyday work of the practice is a long one. Development of organizational routines and standard detail libraries as well as personnel training represent a sizeable part of the overall investment. In addition design practices are not used to make investments of this order.

At present the subject of integrated computer-aided building design is the subject of considerable debate[7]. The concept itself was defined in the early 70-ies and some CAD-systems built in the UK tried to implement it into practice. Valuable experiences were gathered in the process but the target still looms far ahead. During the first half of the 1980-ies the systems actually used in building design have been primarily used as draughting systems[8].

There are basically two ways to achieve integrated computer aided building design. The first option is that all participants use the same CAD-system and its central database, possibly through their own local workstations. Alternatively standards for the exchange of data between different CAD-systems evolve to the point where it is possible to carry out a project with a number of different systems, and still have the benefit of the programs communicating directly with each other.

Until recently only the first option seemed to offer realistic possibilities for reaching integration. It is also fairly obvious that system vendors and CAD service centers are more prone to develope integrated systems based on their own basic CAD-software than trying to cope with "mixed" projects. Today the data exchange capabilities of personal computers and engineering workstations are evolving rapidly. It now seems likely that some form of step by step integration is a viable alternative.

There is thus no single, clear strategy for achieving an integrated system. Market forces constitute the major factor behind integration, but in addition a fair amount of applied research is needed. In the following some product development projects related to integration are presented.

5.2. Enhancements to turnkey systems

The MEDUSA system has captured a large share of the construction market in Sweden. This is to a large extent due to the development and marketing work done by two Swedish firms. Arne Johnssons Ingenjörsbyrå is a large structural consultant which acquired a MEDUSA system in 1981 and started to build symbol libraries and additional software which adapts the system for the needs of building designers (mainly architectural and structural).

DAPAB Ab is a CAD-center formed by a number of HVAC and electrical consultancies to provide CAD services for themselves. At the same time it's also a commercial venture. DAPAB has developed symbols and routines for mechanical and electrical design. Both systems have been tested together in integrated use in the Bollnäs experimental CAD use project described elsewhere in this paper.

The market leader in the computer-aided building design market in Finland is the DOGS software, usually running on DEC VAX 11/750 superminies. As in the Swedish case it is likely that the dominant position of a specific system, which by no means is a market leader internationally, can be explained by its adaption by a CAD-center with sufficient resources for development and marketing. A strong local support for a system is an important decision factor for firms contemplating purchase.

The computer services centre in question, TEKLA Oy, has traditionally catered to structural consultants by making software and selling computing services. TEKLA together with some of its client is at present carrying out a large project for developing DOGS into a tool for integrated computer-aided building design. This requires that the following kinds of software and routines are developed on top of the basic 2-D draughting system:

- Programs for data base management and data transfer in an integrated building process
- Rules for the management of the integrated design process. For instance concerning access rights to the central data base, revisions.
- Menus and symbol libraries for architectural, structural, mechanical and electrical design.
- Programs for taking off quantities.
- An interface between the project data base and a large variety of structural analysis and design programs being offered by TEKLA.
- Dimensioning and design software for HVAC and electrical design.

5.3. Prefabricated single family houses

The design of prefabricated single family houses is an especially attractive area for the use of computer-aided design. There are several reasons for this:

- Very often the design and manufacturing are done within the same firm. The same computer system can thus be through the whole process.
- Prefabricated parts can be placed in libraries and called up during design.
- Since houses are relatively small compared to larger buildings, 3D-visualizations can be produced quite easily.
- A price data base can be connected to the system. Tenders can be made to prospective customers very quickly once the design has been completed. Typically the number of tenders made is between 5 and 10 times the number of completed contracts.
- In the near future databases of houses, for which contracts have been made, can be used as input data for the production planning software of the firm. Important savings can be achieved by more accurate predictions

of the need for different building parts. This is especially important in the Nordic countries where seasonal variations due to the climate are large.
- In the long run customers will have the opportunity to participate more than at present in the design of their house. Alterations to the plans will be easier to make. The customer will not select one house from a range of predesigned solutions but plan it freely, only following the module system imposed by the building parts used.

Software for this application area has been produced especially in Norway and Finland. The Norwegian systems are CAD-HOUSE, DDS, HAMBO and ROBOT. Of these DDS and ROBOT run on 16-bit micros and are fairly recent on the market. CAD-HOUSE and HAMBO run on larger computers and have their roots longer back in time, but have been updated to utilize modern workstation technology.

Without making any qualitative judgement on the merits of the four systems an interesting feature of HAMBO will be presented. The system was originally developed for a combination of the Nord computer with alphanumeric terminals. The specification of the house to be designed was thus originally done by giving alphanumeric commands. In 1984 HAMBO A/S started to shop around for a graphics terminal and surprisingly enough opted for the MacIntosh! Since the MacIntosh is a standalone micro time Tandberg terminal emulation software had to be developed.

Using the MacIntosh has many advantages. The HAMBO program utilizes the userfriendly pop-up menu technique of the micro and its good graphics capabilities. And in addition system users can use all other programs available for the MacIntosh, running it as a standalone machine.

5.4. An example of bottom-up integration

A different approach to integration has been tested in a research project carried out at the Technical Research Centre of Finland[9]. The primary aim of the project was to develope better user interfaces for energy calculation software. Up to the present day many programs for the calculation of the heating energy requirements of buildings have been developed at universities and research institutes. As a result the effort has been directed more towards the development of the calculation methods than the user interfaces.

In the project an easy to use calculation program was developed using the advanced spreadsheet program SYMPHONY. The basic program also contains the possibility for defining macros and windows. In the normal mode the user fills in the data concerning the building geometry (size and direction of walls, windows, u-values etc.), or uses default values.

In addition SYMPHONY contains tools for data communication with larger computers. Files from almost any supermini or mainframe can be downloaded in ASCII format to user defined areas in the speedsheet and can the be processed into the needed format for calculations. In the tests a simple building was created using three commercially available CAD-systems (ICEM, DOGS, INTERGRAPH). The necessary data for the energy calculation was generated interactively on a CAD-workstation and stored in files. After this the SYMPHONY program running on an IBM PC accessed these files and transferred them to the energy calculation templates.

The tests proved that it is relatively easy to build links between existing CAD systems and calculation programs running on microcomputers. Many calculations used in the design process could be more easily implemented on spreadsheets than using the report generation facilities of CAD-systems.

6. CADCAM interfaces

The computer-aided draughting of building plans isn't only an end in itself. The cost savings which can be achieved in the design process are much smaller than the benefits which can be achieved through the use of the building data base as input information to other applications. The most important applications are:

- taking off of quantities and cost estimation
- production planning and management
- computer-aided manufacturing of prefabricated parts
- construction robot systems
- maintenance and facilities management systems.

A number of projects in the Nordic countries are looking at interfaces which are needed in order to achieve these specific types of integration.

In Sweden the design consultancy Arne Johnssons ingenjörsbyrå Ab is studying the use of design databases for the taking off of quantities needed for different purposes. The project is connected to the development of the MEDUSA CAD system. In another recently finished Swedish project the aim was to study how drawings for different uses in the construction process should be structured[10]. The starting point in the project was the layering of the CAD-data bases which enables flexible production of tailormade drawings. One aim of the project was also to develop new drawing types which would be better suited to the needs of the end users.

The use of computer produced plans for prefabricated building parts (wall elements, slabs, columns etc.) as an input for the production planning and eventually computer aided manufacturing (CAM) systems of the prefabrication industry is studied in Finland and Denmark. The key issue in this field is to define a standardized data exchange format between the structural design firms and the factory. At present a number of design offices have developed their own software for the dimensioning and draughting of prefabricated elements, or use draughting systems for this purpose. It is thus almost impossible for the factories to use this information in digital form unless they choose the same CAD-system as the design firm in question.

In both projects the aim is to provide a detailed description of the information which should flow from designer to factory. The Finnish project is more geared towards CAD-applications, whereas the Danish project aims at a standard for alphanumerical descriptions of the building elements.

As of now there are no projects in the Nordic countries which are looking specifically at the interfaces between CAD-systems and robot systems on one hand or between CAD-systems and maintenance, rebuilding and facilities management system on the other hand. It should, however, be mentioned that the Swedish Board of Public Buildings aims to continue the Bollnäs CAD pilot study into the building maintenance phase.

7. Data exchange and draughting standards

7.1. Areas for standardization

The importance of standards as an infrastructure for the development of integrated computer-aided design has been documented in a number of reports [11,12]. The traditional communication between individuals working in the construction industry can be achieved through rather loose conventions which determine the content and format of different documents which are needed in the construction process. The computers of today lack "intelligence" and thus the computer to computer or computer to designer interfaces have to be much more rigorously defined.

The key standardization areas which are relevant to the construction industry fall into two separate categories.
The first category consists of areas which are relevant to software integration in construction, but which the construction industry itself cannot influence. Standardized digital exchange of data is a basic premise for building large computer networks, local area networks etc. Standardization of programming languages and operating systems enhances software portability. Computer graphics is also an important area. The proposed standard for the exchange of data between different CAD-systems, IGES, would if successful be of crucial importance to the building profession.

The latter category includes areas which the construction industry itself controls. If the input and output format for data to the software used for specific tasks in the construction industry could be standardized, important savings in time and resources could be achieved. As an illustration consider the possibility that bills of quantities produced by the CAD-system of the designers could be read directly by the cost estimation and project management software of the contractors.

CAD systems usually contain routines for handling basic geometric entities like points, lines, planes and cylinders. Through combinations of these users can develop applications oriented entities such as walls, doors and structural elements. If a number of designers are accessing the same database containing a model of the building under design these basic entities should be rigorously defined. Up to this date some attempts have been made by making construction industry applications versions of some turnkey CAD-systems (described in the chapter on integrated CAD software development), but no work aiming at a general standard is currently under way in the Nordic countries. The task is in itself extremely difficult, but theoretically attractive. Such standardization would in fact be intimately linked with the work that has been done in the past few decades to standardize building classification systems, an area in which the Swedish construction industry has been a forerunner.

The growing use of CAD has also created some pressure for minor revisions to draughting standards[13]. One part of this pressure originates from the limitations in today's computer graphics for producing certain types of graphics efficiently but another part stems from the greater possibilities offered by computer data bases to produce flexible documentation.

7.2. Standards for the transfer of building document

The Norwegian Council for Building Standardization has developed a standard for the exchange of alphanumerical building documents[14]. The standard especially concerns documents such as building specifications which have been produced on micros using general purpose wordprocessing software.

In the standard five types of data records are defined. Each record consist of 80 alphanumeric ASCII characters. In each record certain fields are reserved for codes defining what information is contained in the record. Most of the fields are left undefined in the standard itself but should be defined by the supplier of the information. The basic idea is that if the "donor" and the "receiver" of the information have different software running on different computers, only conversion software to and from the standard are needed, not conversion software between all specific computers and programs (the IGES-standard uses the same principle).

The Norwegian contractors' organization has also issued a standard proposal, based on the same principles, for the exchange of activity networks[15]. These are typically used in project planning and management software.

7.3. CAD conversion standards

The fact that IGES in its present state has not proved adequate for the exchange of building data between different CAD-systems has lead to the development of partial solution to the problem, the programming of links between specific CAD-systems. In Sweden the Building Research Council has been financing a project for a conversion format between the leading turnkey systems on the Swedish market. Software has in Finland been produced for conversion between the MEDUSA and DOGS systems and will be tested during a trial CAD-project for the Public Building Board As market demand for such conversions grows, "bilateral" software will undoubtedly be developed and sold by the system vendors.

An ambitious project has been started by the BPS-center in Denmark. One premise of the proposal is that IGES, which has originally been created to deal with objects typical in the manufacturing industry, isn't suited to the needs of the building industry. Furthermore it is assumed that it is possible to create a suitable format on the national level, as opposed to the international level. The standard would in the first phase define 2D models with a possibility for later extension to 3D models.

In addition to Denmark a CAD conversion format is under development in Finland. The Finnish conversion format is a part of a larger project aiming at studying and standardizing the exchange of information between structural designers and concrete element factories.

Any conversion format for CAD-data must necessarily compromise between different objectives. In the proposed Finnish format the overriding concern has been to minimize the time needed for transmission of data using modems and telephone lines, which will be the dominant means during the next few years. Since this is a slow medium (typically 9600 Baud) the length of the converted data, measured in bits, should be as short as possible. One major criticism of the IGES standard has been that it tends to result in code many times as long as the original data.

Some of the characteristics of the Finnish exchange format are:
- The data is transmitted as sequential data files in ASCII format
- 80 character line width is used
- All numbers are coded using the visible ASCII characters as integers in a 94-based system. Some can also be stored in the form I*10*J where I and J are 94-based integers.
- The numbers are of variable length. The average number of bytes needed to store a number or a co-ordinate is approximately three.
- Higher precision than 32 bits can be used.
- The graphical entities defined by the GKS standard are used in the standard.
- The file consists of entities of variable length.
- Subroutines written in the FORTRAN-77 binding to GKS write and read the conversion format file.
- Conversion programs for different CAD-systems will be written using these subroutines.

The authors of the standard claim that it manages to condense the information in a CAD database to 2/3 of the original database.

8. Conclusions

The growing use of computers in construction has received quite a lot of attention in the industry press. The number of words written about the subject do not, however, correlate with the actual use of information technology. We are still speaking about a technique which hasn't reached its maturity.

In the long run the main problems in implementing computers in construction will be organization and training. Computing systems are sometimes seen as consisting of hardware, software and "humanware". Developments in hardware usually precede developments in software by at least a couple of years. " Humanware", that is the ability of users to operate computing systems, lags even further behind.

One of the observations that were made during the Nordic study is that organizations concerned with furthering the use of computers in construction have grasped this important fact. This can clearly be seen from the orientation of the research, development and standardization projects studied. It is obvious that the Nordic countries have to import the new technology from abroad. This obviously concerns hardware but also to a large degree software. Development of classification systems, routines for computer use and personnel training, must on the other hand necessarily be a domestic issue.

Some people might argue that we shouldn't import the turnkey systems which are offered from abroad, since they are ill suited to the specific needs of construction firms in the Nordic countries. This might have been true a few years ago. But today there are a large number of very good general purpose programs for tasks like wordprocessing, spreadsheet calculations, 2-D draughting and data base management on the market. Using such programs as a basis for further development saves a lot of time and effort compared to building software from scratch.

There seems to be a widespread consensus in all four countries as to what ought to be the target for national R&D efforts and the reasons behind this. Providing an infrastructure of classification systems and information exchange routines which paves the way for the integration of the computer applications of the different participants in the construction process must, necessarily be a high priority. Such integration will lead to increased productivity in both the design and construction process and will enable Nordic firms to compete for projects in third countries.

The second big priority is better quality in all phases of the process: better presentation of design alternatives to clients, better evaluation of cost consequences of design decisions, less faults in plans, better working conditions for construction workers, and above all better buildings.

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Artificial Intelligence and Artificial Architecture

L. Kroll

Architecture and living surroundings are perhaps the best testing grounds for the myths of Artificial Intelligence and temptations that hesitate between spontaneity and mechanisms and the indulgence in all disguises.

To caricature the contradictions that exist in the actual architectural tendencies, without neglecting the prodigious cleansing of the young Modern Movement had carried out until 1935. It shook up old nostalgia, dead customs, incomprehensible gestures, superstitious techniques. Audacious techniques were proposed, rationalities, calculations, abstractions, objectivism, simplifications within an impetus of iconoclastic and necessary renewal (it is true that they discarded all their instinctive formal heritage.....).

Architects intensively lived these reforms, but sentimental as they are, they would have wished to clear themselves, to distance themselves from "the artist" and disguise themselves as engineers and businessmen (formal suits, horn-rims, etc.). They began to calculate (completely erroneously), to construct "cubist" (and often very attractively...) and to bring about a modern propaganda that no-one liked except the post-war bureaucracy when it used to camouflage the mediocrities of its reconstruction and of its hastily built social dwellings.

The conscience of the "objectivists" underwent self-observation "of oneself doing" by the careful separation of the observer and the observed, by the illusion that the observation did not influence the phenomena, that the observer was not at all implicated and that he grasped all the components of the phenomenon. That which he could not grasp, he ignored.

The delicate process of "decision-creation" of the surroundings was always subtly based on analysis and intuition, on mechanical intelligence and instinct. The empathy with the immediate past and the future never did impede progress; it permitted the project to be added to, to be modelled, to interiorize the existing landscape to create a common object landscape, heterogenous, composite and amicable.

In observing ourselves, we have produced objects, substance outside of ourselves - a show! Previously, our creations were subjective: personal and religious! We partook ourselves of this project and were not spectators or hirelings. And then landscape painting became geopolitic, its manufacture became administrative town-planning; the gardens, green spaces, urban textures; residential zonings, industry became military, cosmogony primary and reasoning binary.

And all of a sudden it seemed that so many inhabitable dwellings, almost new, had to be demolished, that the confused architects had to invent "post modernism", a term that groups all the fugitives from the "Modern Movement" - those who urgently want to modify the appearance of the object without modifying its nature. And by all means: some dress artificial spaces with Corinthian columns (identical to those before), others imitate the regionalist peasant (with running water and television), and again, others become even more inflexible and out of scale or play at the absurd or madness, or else with big toys for children. However, everyone always dreams of imposing his personal order, to organise everything, to militarize, but with travesty. No-one (or nearly no-one) proposes to "let things happen", to follow the natural collective impulse, to listen to the landscape and everyone quickly covers this gap with conviction by demonstrations of force, of technique or of art.

And the old temptations to artificialise human decisions disappear and reappear regularly, under new travesties. Previously, people took cover under Hellenic or Assyrian styles, depending upon whether they were merchants or free-thinkers. Rationality passed through the industrial process: it needed a half-century to unmask totalitarian utopias. And today, they insinuate themselves again into the well meant aspects of the post-modern and propose to trust the thinking machine and then to wash one's hands of the results. And this mercenary merchandise sells well.

We can easily imagine psychologists of Motivational Research linked to Engineers of Methods, being busy to rationally define the necessary styles to entice the customer and produce a feeling of well-being in the slightly anaesthetized inhabitant. They compile a big computer programme of it, with image processing, expert software and then they apply psycho-social aspects in case of neighbourhood difficulties. These are not abstract views, for these attitudes of mothering social actions have been a constant temptation with all reformers going back to Fourier and the Jesuit republic of Paraguay, to certain housing that uses Club Mediterranean as a model. They quickly find architects who are ready to create from nothing, an abstract and definitive cover for a society at last comfortable, but on "scientific" and industrially organised bases. Whereas houses and towns are religious subjects.....

If there was a method (but they can be just attitudes....), it would be the urgency for the re-naturalisation of the artificial because even if it were to take centures to heal the schizophrenias, it always succeeds. It is this meaning that we would like to give the CAO programme we wrote. Its called "Landscape" as it is supposed to build landscapes rather than unbuild them, like most others do. It has several ambitions: firstly, assure CAO like the others, then (and very quickly), demonstrate the project in its geographical and social setting, in colours, in texture and video insertions, then exchange views with all the participants of the construction and at last modify until unanimity is reached. This software is an aid to complexity and communication, not a profit-making tool. It reconciles "components" of industry (not the heavy and ugly pre-fabricated) with the designers and the inhabitants.

It goes against the sence of Artificial Intelligence software used, for example by the MIT which, with lavish means, sterilizes the landscape.

We shall show through slides, operations where, by means of our software, we've used industrialized products without losing on its elements in Marne-la-Vallee, we have drawn a hundred different pavilions in Bordeaux and we have interpreted rehabilitation projects for the tenants of Amiens through infusing our computerized pictures to feed their television cables.......

Development of Advanced Construction Technology Systems utilising Advanced Electronics

Tatsuo Terai

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ABSTRACT

In this paper, outline of a national project called ACT is explained. Its main purpose is to clarify the future image of electronics-oriented technology in Japanese construction industry in 2000, and to make out technical requirements for setting up reasonable emvironment to be needed. The field of research and development is to cover whole activities in the industry. This five year R&D project is devided into six executive sectors in large. Firstly it is devided by its application fild, civil engineering and building construction, secondly by the nature of technology, i.e. software-oriented, hardware-oriented and of their integration.

This project is one of a series of national program called "general project for technical development (GPTD)" sponsored by the Ministry of Construction (MOC). GPTD aims to research such subject as is very important in view of governmental and technical development and general and multi-disciplinary to cover many regions, systematically and organically in good cooperation with private companies, universities and so forth. The system of this program is shortly explained at first.

1. General Project for Technical Development

We have also so many companies big and brisk enough to be considered to do almost everything for themselves. Not a few general contractors and housing makers have their own laboratories nearly equal to the governmental ones. Being strong competitors with each other, basically they need not cooperate especially in applicational fields related to their own profits. It has been widely considered that it is much more difficult to have practical national standard in Japan than in other industrialized countries.

However, it is certain that they realize the necessity of some kind of standard in practice. Actually they keep close contact with each other for long time as for the matter common and general to their usual activities. They realize so well that construction is not closed in the activities only one company can handle with. It is also beneficial for all of them to have social and technical environment in which they can easily and efficiently do their own tasks.

GPTD is one of the largest R&D programs sponsored by MOC. It aims to develop fundamental technology and/or establish suitable bases to be required for improvement of general productivity in construction industry in correspond to the above-mentioned industrial needs. This program is unique in that representatives of governmental, industrial and public research sectors are all supposed to be joining together in one common project.

GPTD is different from other projects in the point that each subject is researched and/or developed in concrete form to be directly applicable to governmental responses in the near future. According to the result of the first project of this program, for example, traditional static calculation method for aseismic performance of building was already replaced by new dynamical aseismic diagnosis method in Japanese building standard regulations.

Each project is planned to be executed with the conditions as follows:

- R&D period is usually for five years
- governmental budget is arround five hundred million yen ($ 2.5 mil)
- averagely two projects will start every year

ACT runs basically on these conditions. This amount of R&D budget is rather small for national project, in comparison with those of projects sponsored by the Ministry of International Trade and Industry (MITI), for example, "The Fifth Generation Computer", "Sunshine" and "Moonlight" project and so on. They spend usually 50 to 200 billion yen ($ 0.25 to 1 billion) totally in one project.

This difference is derived from the nature of each project. Generally speaking, MITI's projects are of manufacturing something hard in the end. The budget is to be spent for practical use, i.e. for tools and materials. On the contrary, MOC's projects are mostly of developping something soft which is useful for evaluation. The budget is to be spent generally for coordination of project committee's activities. Although MOC has also manufacturing-oriented projects, they are usually exclusive of its nature and therefore do not fit so much to general program like GPTD.

Projects carried out or being undertaken are listed here. R&D period is shown in each parentheses in fiscal:

- Development of new aseismic diagnosis method (1972-76)
- Development of costruction techniques for marine structure (1972-76)
- Development of general evaluation system of housing performance (1973-77)
- Development of reasonable construction methods for small houses (1974-75)
- Development of new techniques to improve nature of construction site (1977-79)
- Development of new distribution system (1976-80)
- Development of proper ways to counteract fire disaster in city (1977-81)
- Development of energy saving housing system (1977-81)
- Development of techniques to improve environmental conditions at construction site (1979-81)
- Development of comprehensive techniques to fit up housing environment on heavy traffic road in good order (1978-82)
- Development of techniques to improve building durability (1980-84)
- Development of techniques to utilize waste materials in construction field (1981-85)
- Development of post-earthquake measures for buildings (1981-85)
- Development of design system for building fire safety (1982-86)
- Development of comprehensive technology on the construction of the citiespreventing snowy disaster (1982-86)
- Development of advanced construction technology systems utilizing advanced electronics (1983-87)
- Development of durability improvement of concrete and its structures (1985-87)
- Development of new waste water treatment systems by use of biotechnology (1985-89)

2. Development of Advanced Construction Technology Systems utilizing Advanced Electronics (ACT)

Japan's construction industry, amidst the astounding technological developments taking place in the production sector, is often considered to be lagging behind, remaining one of less modernized industries. However, with the recent slowdown in Japan's once phenomenal economic growth, competition for orders has become increasingly fierce. Many companies have come to realize that they should enhance their comprehensive potenciality by introducing advanced technology into practical fields. Thenceforce, we have many applicational examples. CAD systems and construction robots are already no topics among ordinary engineers and students in this field. We are now in the proceeding stage to evaluate the efficiency of this kind of technological development more carefully and critically than in the past. Along with a growing number of trial applications, many problems have been exposed to enhance their efficiency.

The ACT project is planned to cope with these problems. It could be said that the government realized that increased efforts should be made at the industry and the national levels towards establishing the preconditions necessary for expanding advanced technology utilization.

One of the main subjects to establish them is to make the way clear how to advance construction technology in the sight of integration by properly and effectively utilizing high technology. The ACT system is intended to act as the foundation for integration of data processing and robotization in the near future, and will play a crucial role in determining the nature of the other related R&D activities in Japan.

The field of R&D is not especially restricted in some specific fields as is always the case of these kind of projects, so that this project should basically cover main significant activities in construction in general. Fig.1 shows the field concerned in this project.

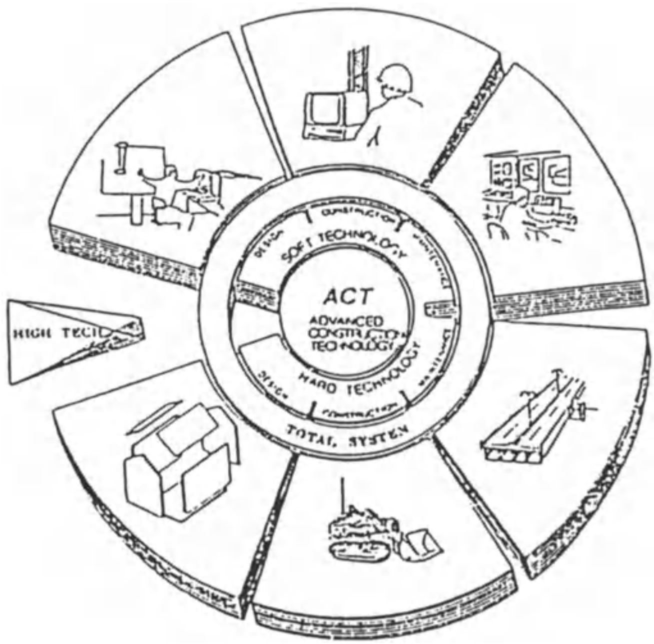
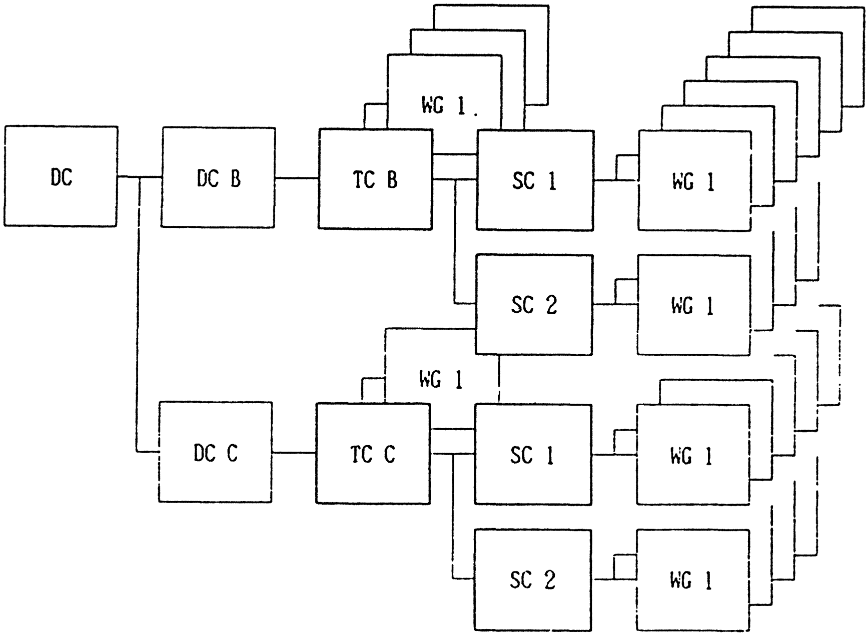


Fig. 1 ACT, new general technical development national project

The diagram consists of a stack of many discs connected with one ring. Each disc is conbined with six leaves. The upper half corresponds to software-oriented, and the lower to hardware-oriented technology. Both are devided into three parts in correspondent to the design and production process in large. This project is to cover almost all production stages from planning to after maintenance and remodelling of objects. There might be much more leaves minutely devided. It is considered that computing technology plays main role in the upper half field and automation technology in the lower half field.

Each disc corresponds to individual activities with relation to the separate application field like bridge-, tunnnel-, road-, office building-, house-construction and so on. The stack of discs is considered to be devided into two main portions, civil engineering and building construction portion, and these portions are basically in charge of the different two research organization of MOC respectively, the Public Works Research Institute and the Building Research Institute. The connecting ring means that there needs some integration between separate R&Dsubprojects. It is required mainly to form initial R&D frameworks and set up some kind of evaluation system for high tech introduction to the related field.

R&D committees are organized as follows :



DC :Development Committee of Avdanvced Construction Technology System utilizing Avdanced Electronics
DC B :Development Committee on Building Construction Technology
TC B :Technical Committee for Advanced Systems in Building Construction
TC B/SC 1:Sub Committee for Soft Technology in Building Construction
SC 2:Sub Committee for Hard Technology in Building Construction
DC C :Development Committee on Civil Engineering Technology
TC C :Technical Committee for Advanced Systems in Civil Engineering
TC C/SC 1:Sub Committee for Soft Technology in Civil Engineering
SC 2:Sub Committee for Hard Technology in Civil Engineering

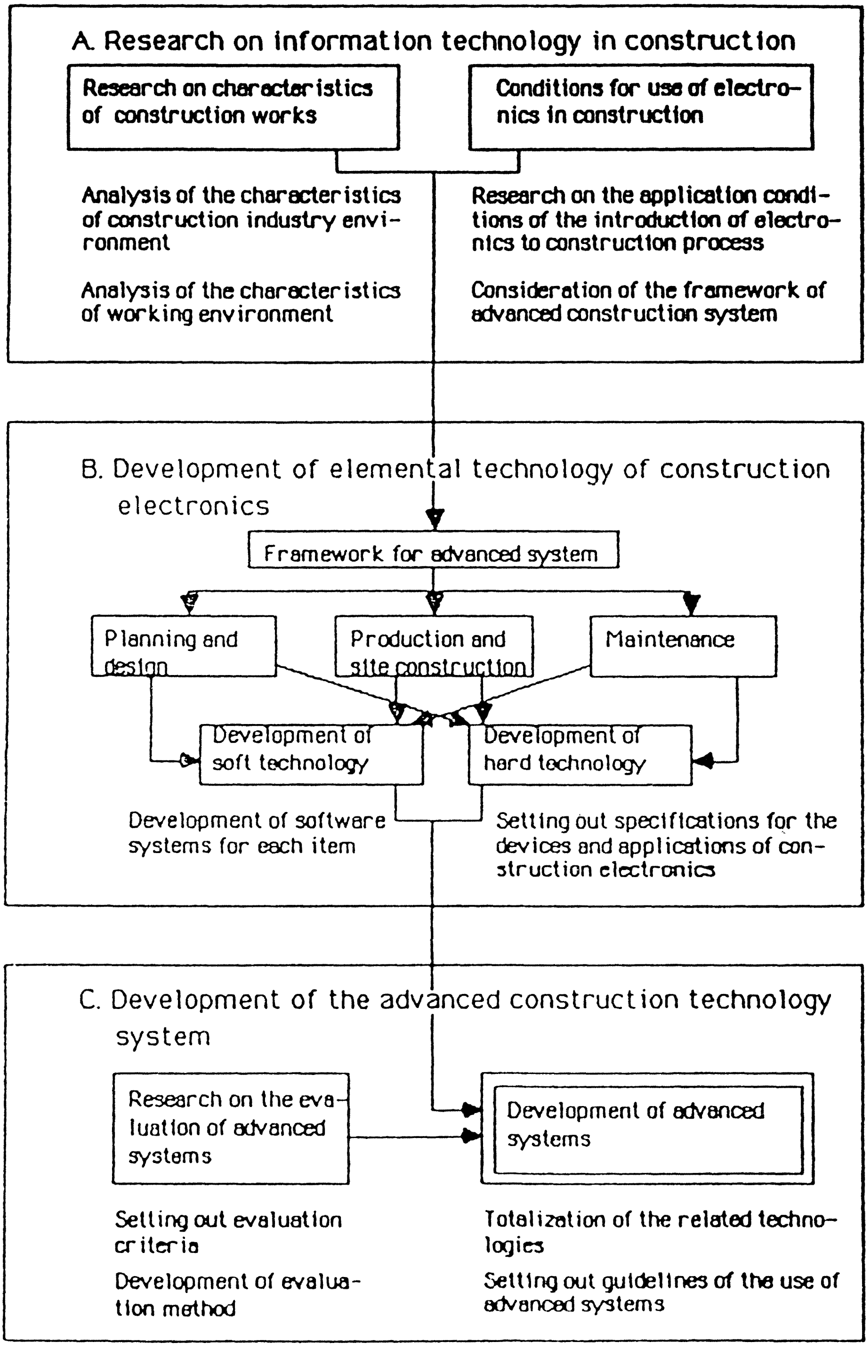


Fig.2 A schematic representation of R&D flow in ACT project

Fig.2 shows the three main subjects and their relations in time flow in this project. Research on subject A is carried out in the first two years (1983-84). Basic framework for R&D is to be established in the first year. R&D on subject B is put into practice in the second year (1984) along with the framework, and lasts for four years to develop a number of sub-systems and establish required specifications related to individual needs. R&D on subject C follows that on subject A in the third year (1985), and formulates individual results into integrated advanced system to be operational in the near future, in the succeeding three years.

The main role of three development committees is to evaluate and coordinate relevant individual R&D results. Practical R&D is to be carried out by the working groups set up in the six committees, two TCs and four SCs. TC B/SC 1 has following six WGs in 1985, for example.

TC B/SC 1 : Sub Commitee for Soft Technology in Building Construction
(R&D Committee for Integrated Information System on Building Production)

Coordination Group
- WG1 : Technology on Systematization
- WG2 : Building Production Method / Design Method
- WG3 : Building Materials and Components
- WG4 : Cost Management
- WG5 : Site Construction
- WG6 : Maintenance and Modernization

3. Main Subjects and the Outline of Results of the two TCs

R&D subjects and the results in each year in the practical committees are outlined in brief as follows:

[Apr.1983 - Mar. 1984]
(TC B)
《Research on characteristics of building construction works》
- Following items were investigated mainly through governmental statistics to characterize building construction industry
  1) trends of construction investment and construction workers and their relationship
  2) present status of productive activities and their productivity in the industry
  3) problems as for building construction works and their characteristics

《Research on conditions for proper use of electronics in the field》
- Analysis on environment surrounding building production system
  Environmental incidences were classified in three levels, and related factors were also put into 10 categories. How they affect to construction was analized at each level. 10 categories are:
  1.population 2.economy 3.industry 4.resources 5.internationalization

6.information society 7.society 8.life 9.administration 10.technology.

- Definition of "advancement" and investigation of its requirements

According to 72 key words related to a image of adnvanced state of each specialist, structure of "advancement" was investigated and the following seven factors were extracted and analized in detail.

1. new method 2.clarification 3.new function 4.higher performance
5. higher effectiveness 6.safety 7.happiness

Then, advancement was tentatively defined as follows:

Description "To be advanced" is applied to such a case as the way or method in use gains some comparable effect on one objective activity.

- Analysis of the present building production system

Construction works on site in one practical project were analized in detail and information were collected as for the following items:

1. comprehensive flow of building production
2. structural elements of production system on site
3. block diagram of organization 4. production process
5. relationship of materials and machinery
6. information system 7. technical elements and their present status

[TC C]

《Research on characteristics of civil engineering works》

- Social and economical trends were arranged in three flows in large, internationalization, human aging and maturity, and evaluated in detail.
- Present status and future trend in civil construction were dealt with and following five factors were analized in detail.

1.investment 2.materials 3.energy 4.labour 5.productivity

- Environment surrounding actual work and related technology were analized, and following three explicit trends were pointed out.

1. partial transferrence of work from site to factory
2. introduction of systematizing technology
3. growing importance of information management system

- Characteristics of civil engineering were explained in 13 items and objectives of development of advanced systems in civil engineering were settled to be the following four points:

1. economical benefit
2. countermeasure for safety
3. countermeasure for labour
4. quality control

《Research on conditions for proper use of electronics in the field 》

- Investigation of applicational cases in the industry

Six levels were set up in each application field with regard to the introduction level of electronics-oriented technology. Basic levels are as follows. Each level was their modification to its own characters.

level 0 : essentially in no need
level 1 : in need but yet not introduced
level 2 : introduced only in small independent work
level 3 : introduced in plural (succeeding) works
level 4 : to be integrated in related closed system
level 5 : to be integrated in overall system

Application fields to be investigated in detail were the following:

1.investigation 2.planning/design 3.construction method
4.measuring method 5.maintenance 6.information management

- Analysis of applicational requrements in cvil engineering

Problems to introduce electronics-oriented technology into related activities were picked up and requirements for effective use were analized in each practical case.

《Research on state of the arts of electronics-related technology 》

- Present status and R&D subjects in need on civil engineering system to

aid information processing were dealt with under following sub-sections:
1. information processing in civil engineering
2. background of introducing computer-aided systems
3. trend of the systems
4. present status of the systems
5. problems of the systems and some related prospects

· Techniques with regard to construction robots
Following five techniques were comprehensively investigated.
1.elementary materials 2.sensing technology 3.information technology 4.actuation technology 5.robotics (in general)

【Apr.1984 - Mar. 1985】
〔TC B〕
《Research on conditions for proper use of electronics in the field 》

· Effects of environmental changes on building production system
10 categories classified in the previous year were re-arranged into the following five ones and their individual impacts on building production were investigated through scenario writing method.
1.market 2.business management 3.labour 4.information 5.technology
Then, each impact was analyzed by portforio method from the point of view of technical difficulty and extent of effectiveness.

· Definition of "advancement" and investigation of its requirements
"Advancement" in building production was defined as follows:
"To be advanced" is applied to such a case in which some sort of efficiency is improved and, at the same time humanity is improved by changing functional structure of productive activity in building production system.
Here, humanity is to be measured by the four performances of WHO, that is, safety, healthy, convenience (efficiency) and comfortability.

· Trend of advancement projects and possibility of use of erectronics
107 so-called advanced R&D cases were picked up out of related articles in construction industrial newspapers in the last three years and investigated from the point of advancement to be defined above.

· Description of building production system
Some ordinary building production works were investigated in detail from the point of view of production organization, information, materials and machinery and activity to clalify description items, minuteness of description and interrelation of the items. According to the result, a description way was proposed on the basis of chain diagram formed by the law of causation.
Examination process was the following:
1. itematization and functional analysis of related elementary works
2. investigation of interrelation between the works
3. clarification of functional structure in the views of I/O flows
4. description of general system model

· Case study on development of advanced building production system
A development process was proposed as a case study to meet with above-mentioned requirements and description way.

〔TC C〕
《Research on conditions for proper use of electronics in the field 》

· R&D was carried out according to the following working flow.

high technology to help the same kind of development projects. TC B/SC 1 may be said to intend to play the former role in general.

Only the outline of R&D in the first research year in fiscal (Apr.1984 - Mar. 1985) is itematized below. It was required in the year to fix the derection and time schedule of R&D and to confirm the feasibility of the development. For further information including succeeding R&D activities in 1985-1986, please refer to the other paper under preparation. It should also be noticed that the term "building production" is used in the wider definition. It basically includes whole process from planning to modernization.

[Title of the subproject]

"R&D on Integration of Information ralated to Building Production"

It was confirmed that this SC aims to clear the way how to rationalize information flow in whole building production process from planning stage to maintenance and modernization stage. It goes without saying that it is very important in this kind of development to utilize related building production information in more integrated fashion through many experts and organizations in the industry. If one intends to introduce higher software-oriented technology, information should be used in much more effective and productive way. To increase information efficiency and productivity, some kind of standards are to be required in many phases in building production on industrial or national level, which should be the main target of the SC.

[Research items with some results in each research subject]

○Planning of total research program and establishment of policy in general
- final output :specifications of integrated system to be required
- advancement :to be defined as advancement in utilization way
- basic policy :more stress on integration than on individual development
- technical level:practically in 1988-90 and prospectively in 2000

○Analysis on way of information processing in building production
- systems to be examined:eight different systems available in the country
- items to be examined :characteristics of building method,organization, information processing way at present and in plan
- one of main outputs :standard format to describe each process

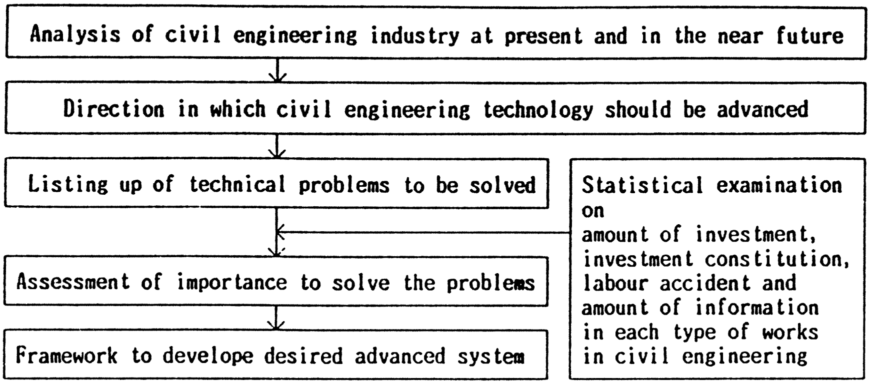
○Analysis on present status of information technology in building industry
- research items:1.present status of R&D on related elementary technology
  2.applicability to building production
  3.necessity of systematization and common use of data &c
  4.characteristics in system configulation

○Analysis on characteristics in manufacturing and distribution of building materials and components.
- characteristics to be investigated for five different systems:
  1.manufacturing method 2.organization 3.trend of diversification
  4.flows of orders and materials 5.open / closed components
  6.level of standardization 7.information processing method

○Typological investigation on cost management systems in building industry
- systems to be examined:seven different systems available in the industry
  * typical two cases abroad (GB and US) were investigated additionally.
- items to be examined :characteristics of related activities
  way of information processing on cost management
  coding system

○Investigation on development method for integrated information processing system in building production

Problems and subjects to be settled were set in order and development way was investigated in the succeeding three years. Accordingly, a flow of R&D program was established. It was also confirmed that major subjects should be to establish common database, knowledgebase and interface rules.



Examples supposed to be advanced were evaluated in the following 8 points.

1. what is to be problem and necessity of improvement
2. importance in solving the problem
3. technical development items to be solved in each problem
4. change of working style caused by improvement to be attained
5. technical applicability to other construction works
6. effect of development including technical applicability
7. difficulty and cost in development
8. comprehensive evaluation of importance of development

84 cases were listed up at the highest rank to be developed according to the evaluation and technical development matters to be solved are also listed up for some principal cases. Advanced levels for each case before and after improvement were also investigated to be summarized as follows:

item	pre-level(max)	post-level(max)
investigation	level 2	level 4
planning/design	2	4
construction method	3	4
measuring method	3	4
maintenance work	2	3
maintenance check	2	4
information managemet	2	4

4. R&D in TC B/SC 1

In this section, R&D in TC B/SC 1 is explained in brief as an example to illustrate the activities in four SCs. The main role of the SCs is to develop relevant sub systems to constitute totalized advanced construction technology system. It is natural to think that there are so many sub systems to be developed. In this point of view, sub system to be developed in each SC should be regarded as only one example of R&D of this kind of project.

Accordingly, R&D subjects adopted by each SC are different in their feature, but it is certain that they must play one or both of the two basic roles. One is to set up some kind of basis to make it easy and feasible to develop a variety of individual applicational projects related to introduction of high technology to the construction industry. The other is to make the way clear through case studies how to develop practical tools and systems with relation to high technology to help the same kind of development projects. TC B/SC 1 may be said to intend to play the former role in general.

Only the outline of R&D in the first research year in fiscal (Apr.1984 - Mar. 1985) is itematized below. It was required in the year to fix the derection and time schedule of R&D and to confirm the feasibility of the development. For further information including succeeding R&D activities in 1985-1986, please refer to the other paper under preparation. It should also be noticed that the term "building production" is used in the wider definition. It basically includes whole process from planning to modernization.

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○Planning of total research program and establishment of policy in general
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Computer Aided Bridge Design

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Campenon Bernard, Clichy, France.

ABSTRACT

An extensive CAD software for bridge design has been developed at CAMPENON BERNARD. It enables the operator to build a realistic 3D model of the structure from wich structural software data files and drawings are partly or totally generated automatically.

1. Introduction

For CAMPENON BERNARD, a major French civil engineering contractor, the use of a CAD system was at first an answer to a drafting problem. Meanwhile the choice of a powerfull system was brought about by the wish to perform a smooth evolution to computer-aided design.

Drawings are nevertheless the main production from the design office. CAD system beeing mainly devoted to draftmen, the aim of the first developpement was to process data exchanges between drafting and design. Drawings, as a main data base for design, are transformed to a computer data base, easily and errorfree processed by structural analysis software.

But there is some differences between a computing model and a drafting model. Many precise details must be drafted, while they are unnecessary for structural analysis.Sometimes inconsistant with software simplification, they are of no mechanical consequence.

The aim of our developpements was to have the design draftman responsible for the preparation of a common model, under the control of the design engineer.

Such software should make the work of the draftsman easier, more precise and shorter while storing the necessary information to generate data files for structural computations.

The choice of bridge structures for this first attempt is hereafter explained, then the different steps of the drafting process are described and analysed.

2. The choice

-A common base between different models
-clear analysis of the design process
-ease of modelling
-programming effort and use of the software

These four criteria led to the choice of bridge structure. That type of structures had always been a major activity of our design office. There are still many bridges to build and a good design software should be usefull for a long time. A large bridge, to be built this year by our company, in Kuwait, confirmed our choice and speeded up the programming.

The process of a bridge study has been analysed precisely with people acting at different levels in multiples studies of that kind of structures.

It can be summarized as two parallel processes, one performed by the engineer, one or more draftsmen beeing in charge of the other one. Constant data exchanges is the price to pay for a complete accord between both results.

On the drafting part, the work begins with the lay-out of the structure in the given site in order to exactly define its geometry. The bridge is then divided into parts or segments and the different bearings located.

A first prestress scheme is defined with parts or elements added to the deck as bracings and prestress anchor blisters.

Making of drawings can start, then rebar placement and detailing using the former plans as reference drawings.

On the design side, the mechanical characteristics are first set. Section design and bearing location are modified in order to improve structural resistance and to minimise quantities. The prestress scheme is then designed and modified till the best results are obtained. Computations on the complete structure give final information on stresses in the bridge and allows the engineer to point out critical parts for him to design special reinforcement.

Data exchanges are numerous because that kind of work is an interactive process based on checking of geometry by draftsman and checking of structural behaviour by the engineer.

A bridge structure model can be compared to a ruled tube from section to section following a spatial axis. This tube is cut into segments to which particular parts are attached. Prestress cables are modelled by cylinders with variing axes.

Programming was not difficult, for the following reasons. First, the bridge structure is mainly linear which simplifies understanding of the problems which are liable to occur. The second reason was the opportunity to use three ready home-made softwares dealing with that kind of work:

-CP as a structures lay-out computation software from alphanumeric data files.

-CO as computation software for expected loss of prestress loads in cables.

-CDB or bar/structure analysis software specialized for bridges.

Bridge design,even for a small one always involves much work and requires a great volume of documentation. Details often have to clearly define typical parts. That kind of study needed a software that is able to reduce the work.

The availibility of a new INTERGRAPH software for concrete detailing provided us with a usefull solution to complete our design software.

3. Structure lay-out

The structure is positioned in space with the help of two plannar definitions, the site view and the profile line.

Site plan view is a projection of the reference axis of the structure upon an horizontal plane. It is defined by points of precise coordinates linked by simple elements (circles, lines) or by connection elements (conic, spirals). Elements are analytically defined or geometrically drawn by their particular properties as tangency and perpendicularity. Computations are very precised, the results are often to the millimeter even for radii of more than 1 kilometer.

The profile line gives the level of every point of the plan reference line. It usualy consists of straight lines and conics.

Construction lines are drafted in a 3D file, on two perpendicular planes.

On each curve, particular points are defined as indications of the major geometrical changes of the deck.

A 3D curve is automatically generated. More than a curve, points are placed in space. Every point is the location of piers or represents changes of the structure which leads to section modification. These points often mark a discontinuity in the construction process or precast element fabrication.

4. Sections drafting (fig. 1)

Bridge sections while varying a lot, always still have some common characteristics between them.

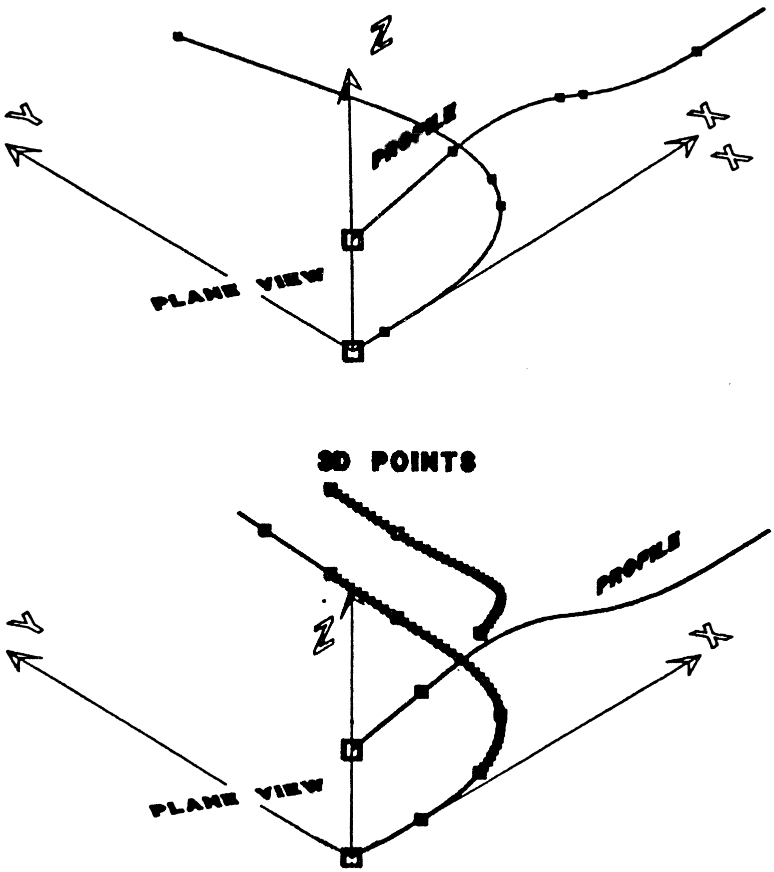


Fig. 1 - Layout curves

A bridge section consists of slabs and webs. It can be open or closed with one or more openings. Symetrical or not, its shape is directly linked to its behavioural properties. It is one of the variables in the calculations, and cannot be fixed at the beginning.

For these reasons, we had to imagine an evolutionary process, free enough to allow any particularity while offering practical tools for drafting usual shapes.

Before they are recorded, different mechanical properties are computed and listed. Modifications are easy and quick, especially if these modifications are the usual geometrical changes applied to sections to improve their behavourial properties such as thickening of slabs and webs.

These sections are named and stored in a library. They can be recalled at any moment for any project.

5. Placing the sections (fig. 2)

In addition to the mechanical and geometrical parameters, some more data linked to layout process are defined for each section. Attachment point to reference curve, superelevation points and theoretical mechanical axis for computation are defined. Some reference points can be added too, in order to identify, after the completion of the structural design process, the final coordinates of the different parts, which is usefull for construction.

Sections are placed, giving for each attachement point on the curve the following parameters:

- Name of the section : in some cases, two sections may be attached to the same point. If so, for each, an indication of wether it is left or right must be entered. It is allowed to make some break in continuity of the section.
- Crossfall of the section above horizontal line.

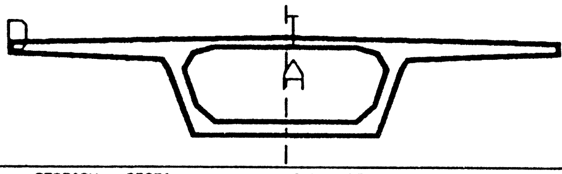
6. Volume generation (fig. 2.II & 2.III)

From the positioned sections, volumes are automatically generated from one section to another. The usual variation is linear but it can also be parabolic or user defined. One restriction is that sections must be defined with the same number of points all along the project, even if some points are geometrically at the same place.

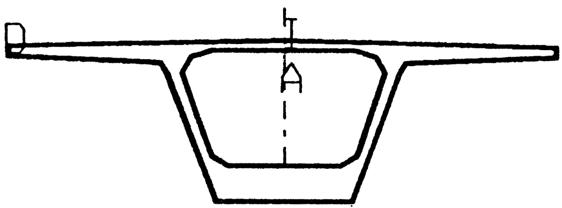
Erection of piers is done in the same manner. They are in fact very similar to the deck, in their design process.

7. Prestress cables (fig. 3.I)

Two types of prestressing techniques are used wich need totally different processes to be generated.



SECTION : SECT1		MIDDLE OF SPAN			
POINT DE DEVERS		POINT D'AXE		CENTRE DE GRAVITE	
-9.0000 -0.1000		0.0000 -1.3705		0.0000 -1.0540	
SURFACE 12.2900		ROTATION DES AXES PRINCIPAUX D'INERTIE 0.000 DEGRES			
	INERTIES	V1	V2	SR	ZG
X	13.3460	1.0540	-1.9460	3.3572	2.3467
Y	243.5845	9.0000	-9.0000	9.8795	10.3479



SECTION : SECT2		SECTION ON PIER			
POINT DE DEVERS		POINT D'AXE		CENTRE DE GRAVITE	
-9.0000 -0.1000		0.0000 -1.3705		0.0000 -1.0540	
SURFACE 12.2900		ROTATION DES AXES PRINCIPAUX D'INERTIE 0.000 DEGRES			
	INERTIES	V1	V2	SR	ZG
X	13.3460	1.0540	-1.9460	3.3572	2.3467
Y	243.5845	9.0000	-9.0000	9.8795	10.3479

Fig. 2 - Sections generation

Cables placed externally to the structure are the easiest to design. Tendons are linked to concrete at some particular points, such as a deflacting block, wich modify their direction. The constitution of such a cable is made of lines linked by circular arcs at attachement points. It is often defined by theoretical points where lines cross, wich are also the points where loads concentrate. Circular arcs are determined as fillets between lines, with a given radius. The direction of the cable model is left to the draftman. Once the model is defined, all the

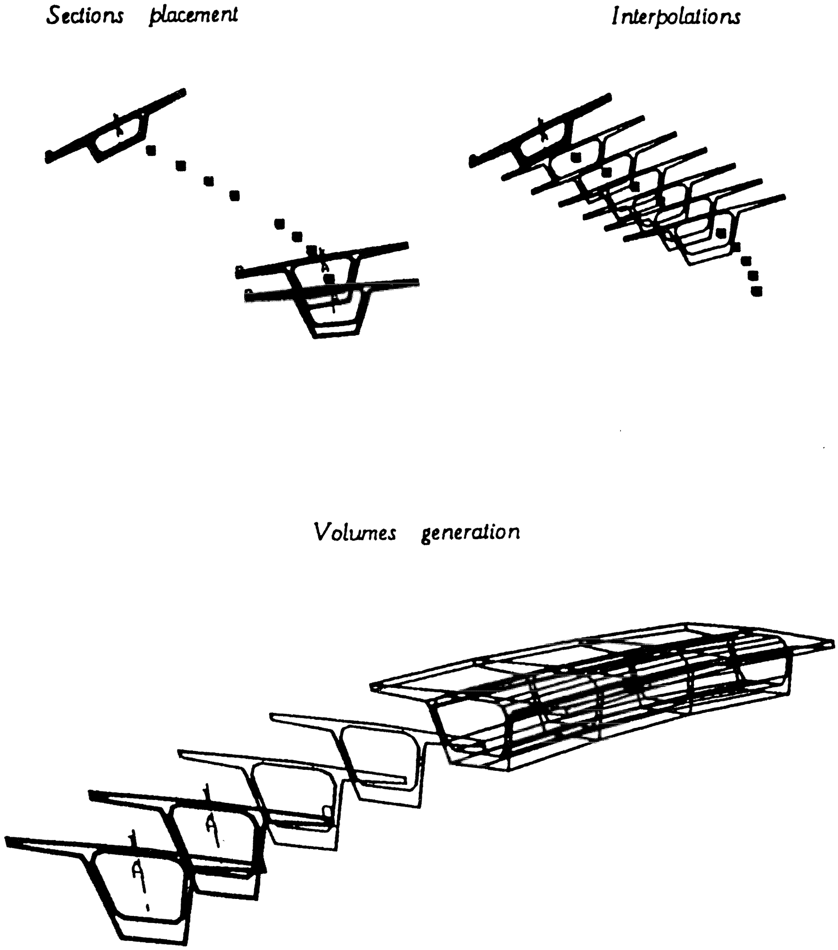


Fig. 3 - Sections and volumes

different parts are linked together, and software is called upon to transform all this information into a coherent system. A facility is provided to the operator to perform difficult connections such as for non coplanar lines.

For internal cables, definition is totaly different. Some leading points are imposed. In sections, positions are often the same from cable to cable in the different sections. Geometrical interpolation between these points have to follow given rules. Ends near the anchorages are often the same too, in order to make design and construction easier and to reduce cost. For that reason, the user is helped as much as possible to easily define that kind of cable.

Imposed points are defined in a data file by their local coordinates inside the sections. Typical end points are studied and designed before the cable is defined. Interpolated with a 50 points-curve, they can be called for any cable.

Tendons are then generated by a batch job. They are aproximated by cubic parabolae. Imposed points between sections or new ones can be defined, some can be suppressed or moved to another place.

For both types, additional parameters are defined for each cable. The type of the cable, the different mechanical properties and the initial stressing load are input in order to get the final tension and expected loss. After modification, these results can be obtained interactively allowing the best definition to be found.

Cables are modelled by their central axis only. For spare economy and minimized response time, it is useless to model the sheath. But in particular points, for interference checking, an overall dimension tube can be automatically generated giving two points on the cable.

8. Anchor block definition (fig. 3.II & 3.III)

Anchor block design has always been the most difficult part in bridge drafting, due to the complicated geometrical definition of these parts. If we try to simply define an anchor block, it is made of a dimension imposed face on wich rests the metal anchor plate, perpendicular to the axis of the cable. Pyramidal facets are the drawn to obtain the jonction with the surrounded concrete base. In order to simplify design and construction, shapes are often the sames for every anchor, even if the concrete base is different, leading to some simple geometrical modifications and adjustments.

Two different steps are taken to define these blocks . First, geometry is defined for each, including fixed dimension in front and variable facet on its side. Once defined, they are collected in a common library and automatically set at the end of the cables in accordance with a given data file within a batch job.

As they have been drawn as a graphic group, they can be reoriented after placement in order to improve access for jack. Once they are definitively set, variable facets are automatically adjusted to be linked to the existing concrete surface.

9. Computing input files generation

Until then, the work performed by draftsmen has been identical to the one they should have done before, but much easier and quicker. As he is processing, much of the information is recorded for later use. With the help of the engineer, some parameters, directly linked to computation software as nodes and bars definition, sub-cutting and connections, internal as well as external, are defined.

The software will automatically generate input data files for structural analysis software.

The engineer will have only to define external loads and get the results of the computation.

10. Graphical extension

All the informations collected can also be used for the graphics. First, form plans are drafted from different parts of the model, automatic references and titles are added. No more difficult geometrical calculation is needed for complex shapes, software simply uses coordinates data from the real sized model. Hidden lines removal and automatic perspective generation is often used to add detailed views wich make the plan more easily readable and understandable by everybody. (fig. 4)

The drafting activity most aided by this facility is the preparation of prestress cables plans. On the longitudinal profile, for each point of the cable much information can be automatically written as name, local radius or slope. A set of section plans can be automatically generated to, giving for each defined section the position of the cables going through it with exact local coordinates. (fig. 5)

Bench marks set on each sections can also be collected on setting plans in order to help the making and placement of segments.

The Model is also used as a reference for reinforcement placement.

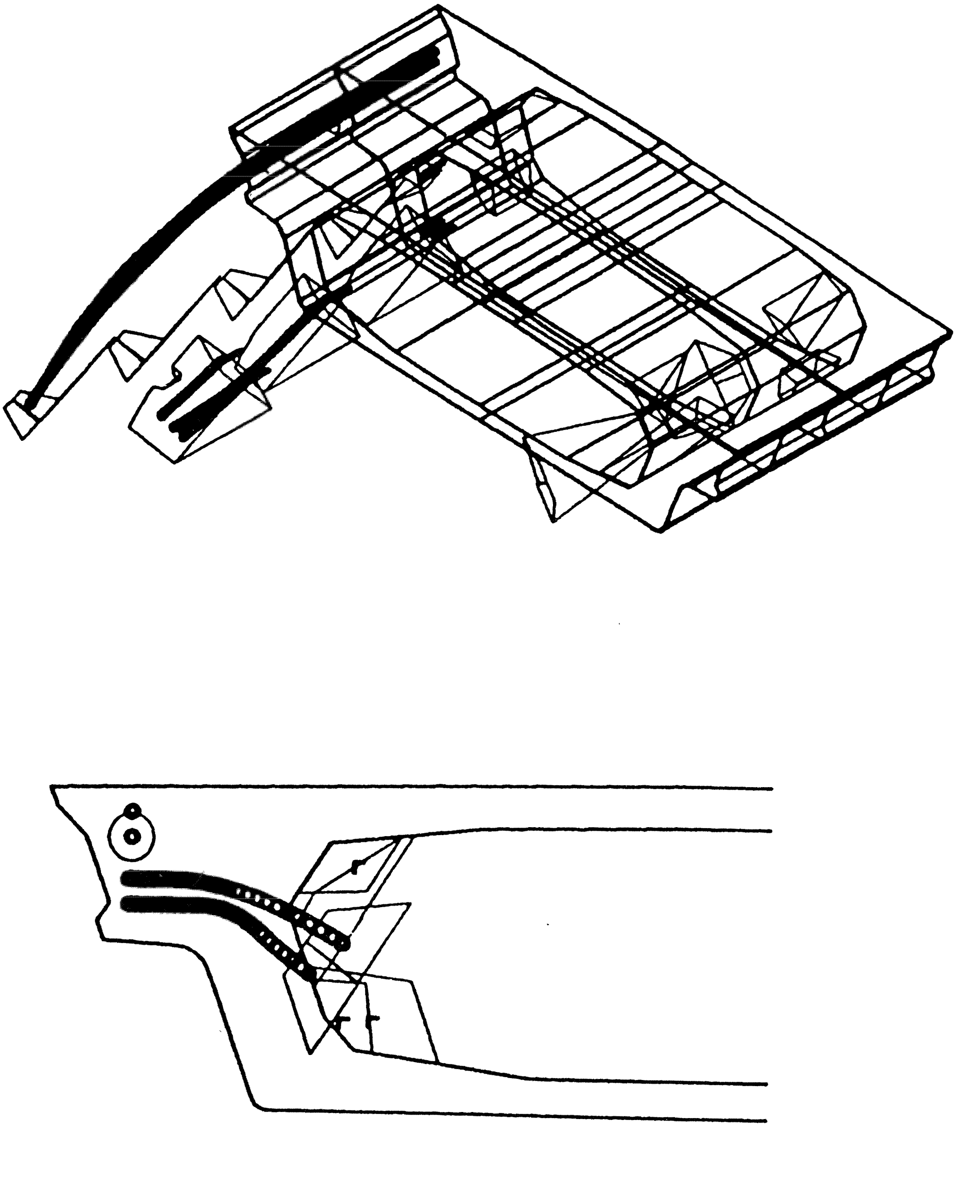


Fig. 4 - Cables placement

No 2D interpretation of the model is required. Bars are directly defined inside the concrete model using the INTERGRAPH CDP software. The aim of this software is to provide an automatic check of the major rules of

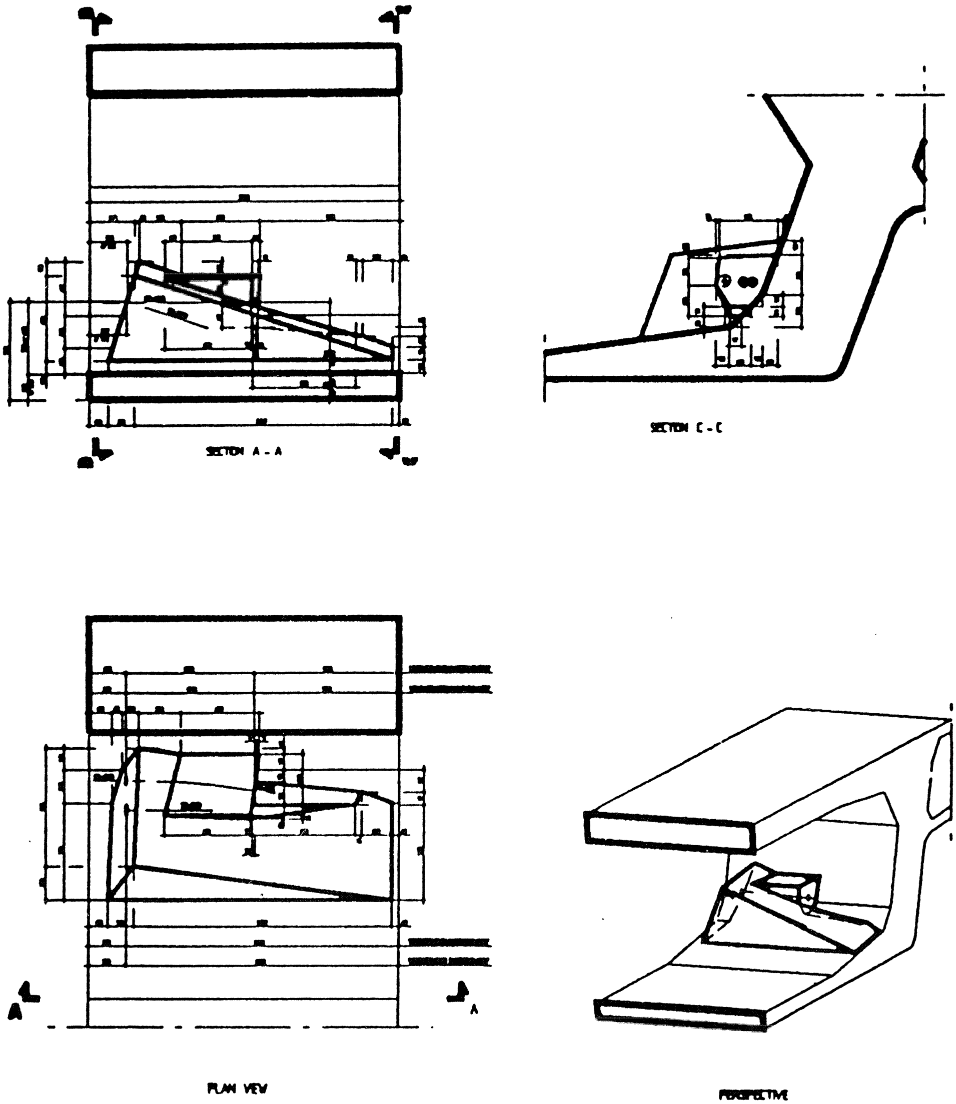


Fig. 5 - Formworks drawings

rebars placement in accordance with several major standards (ACI,CP100,BAEL). Freed from this, the draftsman can design better reinforcement. At the end of the work, sections and detail views are

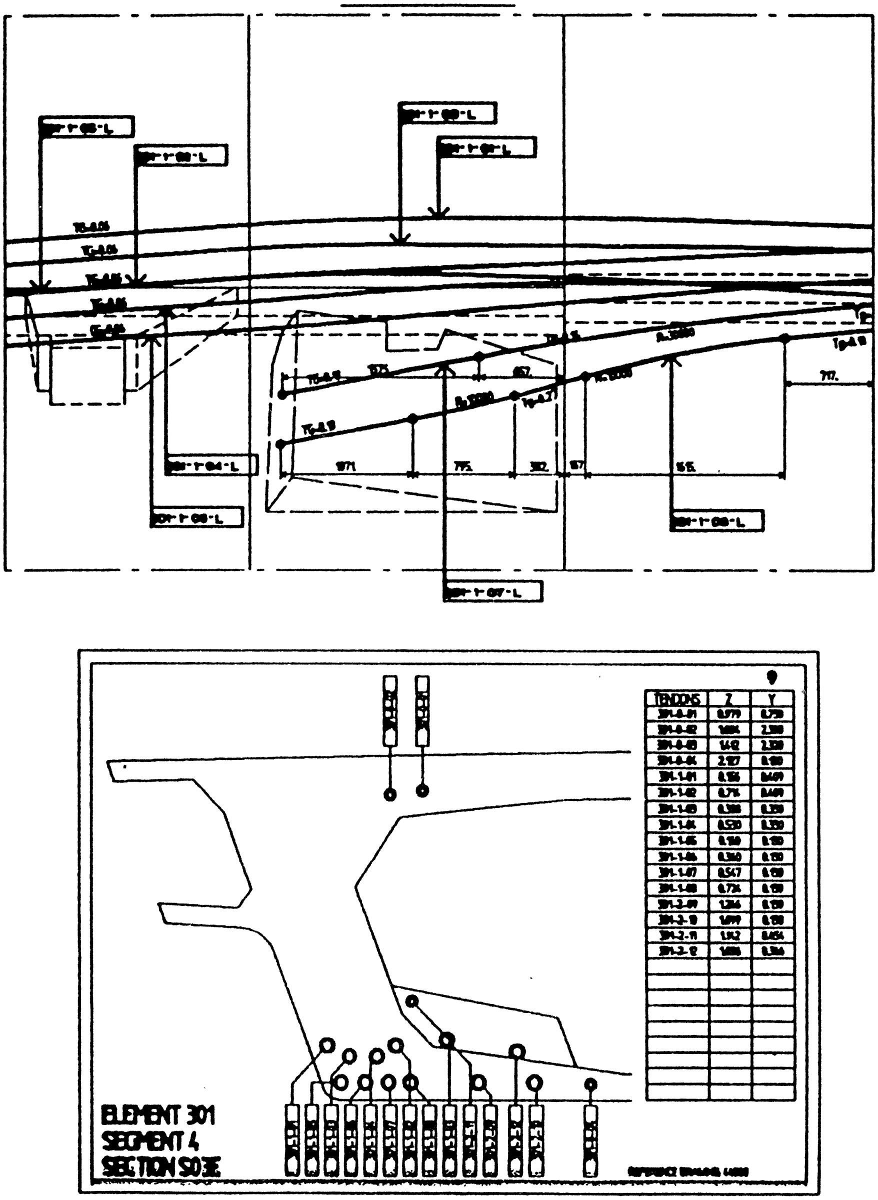
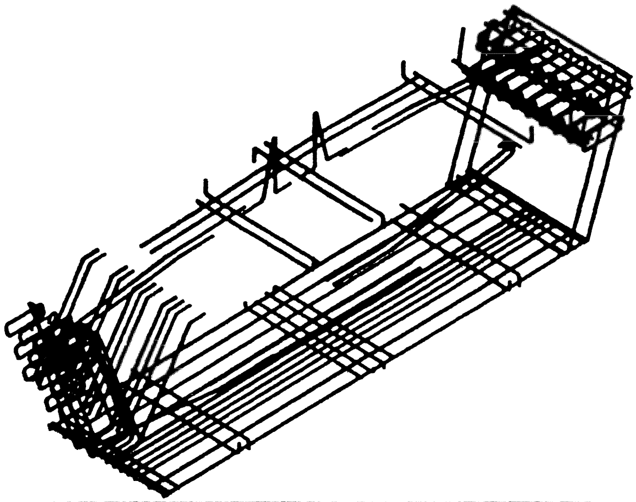


Fig. 6 - Prestressing drawings

automatically generated, for assisting quantity takeoffs.

Report and bending schedules are drawn automatically too .With the help of interference checking, the draftman is able to draw more realistic plan of reinforcement.(fig. 6 & 7)



INDIVIDUAL BAR MARK ON ... DRAWING		NUMBER	DIAMETER			BAR QUANTITY	BENDING SCHEDULE	BAR LENGTH	TOTAL LENGTH
			D	R	S				
AB		1041	10			20	400, 242, 242, 400	[illegible]	[illegible]
AB		1083	10			6	2400	2400	14400
AB		1211	10			8	270, 195, 231, 272	1104	8832

Fig. 7 - Reinforcement

11. Conclusion

This major development needed more than one and a half year-man of programming. However, that important work has been done in understanding the basic softwares.

The first use of that software showed an important saving of time and more consistency in design.

We had given consideration wether we have to go further in automation of modelling process, eg. prestress optimisation. In fact, the bridges studied at the design office are too different from each other to find a common calculation method for geometrical optimisation and get the best results.

As of now, this software with the help and speed it provides, allows the enge neer to design a greater number variant models to select the best one.

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