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Information Technology Straight Across Swedish Architecture And Construction

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FOREWORD

The construction industry is one of the last sectors to start making use of information technology. For example, architectural and technical construction companies have only during the last few years started to substantially apply computer aids - CAD -in their planning and design. This has taken place without the formulation of a strategy for introducing the new technology. The computers have come to be integrated in the work process organized for manual planning and design. Outdated ways of working have been desperately kept up. Therefore, the efficiency opportunities of the new technology have not been fully utilized. CAD technology has only been used for making drawings - to *draw* houses.

In the system under development now, the buildings will be *modelled*. Facts and good examples are derived from databases which makes it possible to reuse and refine various solutions. Computer systems will support problem solving, layout and design. Information technology will put architects and technical consultants to the test and the actual change of working method will require a major awareness by management people.

The purpose of this book is to describe some of the factors of change which make development urgent. The idea is trying to bring to life, by contributions to a debate and hopefully in an understandable manner, a

subject field which is often regarded as technical, difficult of access, and distant.

With one foot in theory and the other foot in practice I have seen the introduction of computer technology into architecture and construction from two sides. I have collected material for this book during my six years as adjunct professor of computer aided design and visualization at the Department of Building Design at the School of Architecture, Chalmers University of Technology. The book is a fusion of earlier published articles, lectures and notes which I have collected during my years at Chalmers.

Many experiences also derive from the development work with the first Swedish CAD application using personal computers for architects, ArCad, which I have been responsible for since 1980. As a practicing architect I have started to use computer technology in my own architectural office and so gained experience from every practical detail as regards the introduction of a new aid in an old profession. It is evident that the change of technology in practice gives rise to many amusing and disquieting objections.

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INTRODUCTION

"Particularly within architecture there exist two principal points: that which is designated and that which designates. That which is designated is the thing suggested and which is talked about, and that which designates is the presentation made of this".

This was written by Vitruvius in the first book on architecture, "De architectura libri decem" which was published exactly 2,000 years ago. He distinguishes between the building and the means of expression of architecture on the one hand and the drawing and its idiom on the other. Vitruvius places in focus the relationship between the architect and his clients:

"Before starting to build, he should make sure that no controversial issues remain which the house owner will have to take care of after finished work. The interests of both client and building contractor should be satisfied when the contract is made up, and the contract must not contain any ambiguous term which could give rise to a law suit between them".

With a mutual conception of the finished project as a basis, agreements are made on the project economy and the division of responsibility between client, planner, contractor and manager. This early conception or "mental" picture which is sometimes given a concrete form by simple sketches is successively added to during the course of the

project work. Typical of the work are the many revisions due to the fact that it is gradually made clear to the participants how the project should really look like. This insight is gained exactly by working with the project. It is important to know how to capture and make use of the increased know-how. The architect's many tools here serve the vital purpose of illustrating in an understandable manner what has not yet been built. To visualize, to make visible what has not yet been built, is therefore in my opinion a central mission in architectural work.

For the first time since Vitruvius, the computer gives us an entirely new tool to improve communication in a revolutionary way between architect, client and building constructor. This happens at a point in time when the Swedish construction sector is in its most severe crisis within living memory. Nobody knows what the construction sector will look like after the peak of this crisis. However, the outlines of a future, new way of working in planning and design, construction and management may be envisaged, and information technology will play an important part here.

The future role of architects may seem unclear and confusing to today's architects, but so it did to Vitruvius:

"Other architects are walking around asking for possibilities to practice their profession; but I have learnt from my teachers that an architect should wait until he is asked to undertake a job, and that he cannot without blushing put a question which makes him seem interested. It is in actual fact those who can do somebody a favour who are approached, not those who are ready to receive it. What do we really want someone to think whom we ask to entrust us with part of his fortune for a big project, except that we make this petition to become rich on his behalf?

This is why our ancestors never entrusted an architect with anything without first having made inquiries about his origin and his upbringing; they preferred the modest one before the impudent and self-assured one. And the architects themselves only trained their own sons or relations and made them righteous human beings.

Today, however, when I see this distinguished profession being freely practiced by uneducated and incompetent people who are ignorant not only of the architectural rules but also of the trade itself, I cannot enough praise the supporter of a family who trusts his own knowledge and leads the construction work himself; instead of entrusting his work to inexperienced people, he prefers to do it according to his own taste as he himself bears the cost."

Vitruvius draws the following conclusion: "Therefore, I have found it suitable to write a comprehensive manual on architecture and its methods". He makes a contribution to the development of architecture in a way other than creating a few buildings.

These words are worth considering also in view of the fact that only every third building permit in Sweden has a person with architectural training as its originator. Two out of three building permits do not have this. A glance at the files of a local housing committee with the many inaccurate drawings gives you a frightening impression of trash and amateurism. No doubt, this is reflected in our cities and landscape. Sharpening one's senses and expressing oneself in drawings and descriptions by means of good documentation techniques is an excellent way of contributing to the art of good architecture.

1 A SMART CONSTRUCTION PROCESS

Doomed!

This is the way the Svenska Dagbladet (Swedish national morning paper) in its trade and economy supplement of the last Sunday of January 1993 described the construction and real estate sector, and simultaneously recommended the shares of an architectural company as the best purchase of real estate shares on the stock exchange. Certainly, the architectural business of the company is probably estimated at zero, but the high yield of the real estate and the fact that the company's liquid assets are larger than its interest bearing debts contribute to make the company heavily underrated, according to the analytical writer.

This well-managed company is FFNS and is the only Swedish architectural company quoted on the stock exchange so far. But this praise may be interpreted in another way. The real estate and liquid assets are given all the attention - the architectural business is not seen as the major asset. This is a very narrow judgement of a know-how based company. To a large extent, its value consists of the total competence of the staff.

The writer also touches upon one of the most strategic issues in the architectural companies' annual reports, i.e. the valuation of ongoing work. By this valuation, the companies' actual profit or loss is determined. To objectively assess projects extending many years into future, and

whose results cannot be finally recorded until final inspections and time of guarantee are over, is a delicate business. But the value of a company's volume of well-managed projects is also its possibilities of generating new business in future. Here we find the companies' hidden reserves. Therefore, reading an architectural company's annual report is not as easy as the writer seems to believe.

The 1993 crisis in the construction sector

If the architectural part of Sweden's largest and best managed architectural company is estimated at zero by an uninitiated reviewer, is this then an indication of a negative situation for the architectural companies in general?

When White Architects, the second largest architectural company in Sweden, gave notice of termination to a small number of employees in December 1990, the radio news considered this to be worth attention. Two years later, the company has been almost halved and has decreased salaries by 10-15 %. "But the major decline will come next winter", says the managing director to Dagens Industri (financial paper) in January 1993, "and then we will have cut down our costs further so that we can survive the crisis".

At the same time a third, very large architectural and consulting company, K-konsult, winds up their architectural business, among other things by offering the regional managers to take over their offices. Their business should in future only be local according to the journal Byggindustrin (Construction Industry).

A series of dismissals and close downs have led to an open unemployment among architects in Sweden of 25 % this month of January 1993, but the inofficial percentage is higher. The many one-man operators disguise the actual, higher rates of unemployment. Suspension of payment, reorganizations and bankruptcies have hit well-established architectural companies and their clients and suppliers. Companies have been "saved" by giving notice to the whole staff. Hibernation was a strategy used in the initial phase of the crisis, but this was not enough when the crisis was drawn-out. The major fall of architectural companies is expected for the autumn of 1993. A symbol project like The Globe in Stockholm has brought with it many victims among construction, real estate and architectural companies.

By the turn of the year 1992/93 approx. 110,000 of the construction sector's 600,000 employees were out of work and the forecast shows that in the winter of 1993/94 the amount may rise to approx. 200,000. According to Statistics Sweden, 2,727 companies went bankrupt in 1992. Out of the previously 12-15 large construction companies, only 5 remain by now. A good guess is that the concentration will increase further and that one or two of the companies will have foreign ownership. The shares are cheap right now.

Also the technical consulting companies have suffered hard. VBB VIAK AB have successively reduced the number of employees from 2,700 to 2,050 by March 1993. The stock prices of engineering companies have collapsed to a tenth of all-time-high. The turnover in the building material industry has decreased by almost 50 %. For example, the turnover of the company Betongindustri AB has in a short time fallen from approx. MSEK 700 to approx. MSEK 400. The private home market

has almost disappeared and the consequence of this has been considerable dismissals and bankruptcies in this sector.

Thus, it is a question of much more than a painful, but necessary adjustment to depressed trade conditions. Instead, extensive resources are knocked out for good in one of our most important lines of business. Among other things, this is the result of speculative building and financing and real estate companies' transactions during the 1980s. The building crisis is to a large extent due to the fact that the companies have made severe mistakes when estimating the economy of the many building and real estate projects.

So far, the construction sector has not been able to make good use of the tremendous dynamics in consequence of the deregulation in the construction sector and the alterations in the financing of residential properties. A sad illustration to this is the over 12,000 building sites with soil and foundations inspected before the turn of the year, which are still waiting for financing. The banks rightly refuse to lend money to this. First there must be a proved market for these houses.

It is difficult to grasp the vacancy degree in commercial premises. Approx. one million square metres are said to be empty in Stockholm, where prices have fallen by over 20 % since the turn of the year 1990/91. Certain experts believe that this vacancy degree may reach American levels of 15-20 %. The commercial office area is 24 million square metres in this country. The reduction of the public sector is estimated to add 100,000 square metres yearly of empty premises during the 1990s.

Has Sweden then no more need for construction work, as is sometimes said?

In such a case, the present building stock would satisfy each future and new type of activity, in terms of contents and location, and the houses would suddenly have stopped ageing. No, even if the number of square metres of housing and premises is enough for a long time ahead, new activities require premises of a specific nature. The premises and houses must have the right location, and houses are surely getting old and worn down. There is always a need for both new constructions and reconstructions. A perspective back in time of a hundred years shows that strong decline and crises in the construction sector have been followed by recovery and, sooner or later, by more construction business than ever before.

Of course, architects, technical consultants as well as constructors and the materials industry will be needed to meet the future demands by the clients, but the building market will change a lot.

It is all clear that the building crisis has involved great changes for consultants and contractors, but the changes are also great for the clients. They will find new roles as purchasers, owners and managers in very professional organizations. For example, the National Swedish Board of Public Building has been divided into two corporations and two administering authorities, the real estate divisions of local authorities and county councils will have a company-like organization, and banks and insurance companies are involuntarily becoming large real estate owners. The proposed bill that all public real estate management should be subjected to competitive procurement, whether the owner authority wants it or not, will make this picture change. If the authorities are unable to attend to their management at the lowest comparative cost, there will be privatization, according to the bill.

A number of factors also point to the fact that the way of drawing, building and managing houses will change. A new role for architects will emerge. In this change, our ability to utilize the new information technology in the right way will be of great importance.

What was done during the last building crisis?

Fifty years ago, the construction sector itself made a real effort to speed up development again. Through so called housing habit investigations, they found out what kind of housing people wanted and how this should be arranged. They reviewed and evaluated what was already built. In a way this could be called a market investigation of the time.

Architects and constructors developed a quality thinking by standardization and spread the know-how within the sector by creating a literature service. New building materials were developed to enable the building of residential housing at prices which people could afford. The Swedish Council for Building Research (BFR), the Building Standards Institution, and the Swedish Building Centre, very important to the Swedish construction sector, recently all reached the age of 50.

What changes will the Swedish construction sector have to go through?

From the million programme to small, unique projects

Today's construction sector originates from the so called "million programme" of the 1960s in Sweden. The large restructuring of construction, materials and technical consulting companies which started

then was not finished until long after the social mission of building a million new habitations in ten years was fulfilled.

Today, 30 years later, we still work in a sector which is mainly organized for this purpose. This sets its mark on our view of the organization of the construction process and the nature of the internal division of roles between the companies, how to work out the documents and how to procure planning and design as well as production. It is also reflected in the regulation systems and directions of the construction sector and in our trade associations' mode of working.

Because of this we have a large, built-in inertia counteracting changes and a lack of interest in accepting reality as it is. The ROT programme (repair, rebuilding and extension) from the mid 1980s was a small step towards a change, but it was interrupted and the speculative building of the latter part of the 1980s was more a return to the million-programme pattern. Then there was no time for the construction sector to change its way of working - all that was built was apparently possible to sell. Now the sector will have to be organized according to its new mission, many small and unique projects and management of the extensive number of buildings. We will go from new constructions on virgin soil to real estate management.

From guild to activity thinking

There exists a deeply rooted image of an efficient, successive construction process which step by step goes in only one direction from A to B to C.

Here there are now strict border-lines between the design, construction and management phases. Various parties should under penalty of a fine deliver their documents and products in a determined

order, and by adding all these product parts, the building is produced. In this process, each occupational group participates only for short periods. The costs of each contribution are cut down as much as possible.

Much trouble has been taken to make the process more efficient, reduce the periods of time, and formalize the procedures. Gone are the handshakes and the quiet professional-pride agreements on how to effect a good job. Now we are looking for faults afterwards and claim damages from each other. The idea is considered to be that the know-how built up by a professional group at one stage should be compiled in documents and be handed over to another professional group for work at the next stage. Here there is a lack of insight of the difference between information stored in documents and know-how live in a human being. To make use of this know-how, architects and constructors must instead follow the project during the whole process when the building is coming into being and the border-lines between the different stages must be crossed.

Our image of an ideal construction process must in the future become more comprehensive. The necessary, linear perspective must be supplemented by the picture of the know-how spiral, and the artistic way of working must have as much room as the technical part. Anyone who has experienced a number of trivial design and construction meetings knows that this would mean a real cultural revolution in the construction process.

The know-how built up at early stages should be passed on, evolved and brought over to those who are to manage and use the project. We will have a new type of project leaders, whose task it is to keep the project's aim and main outlines live throughout the long process. Thus, this is not

someone who breaks the project down into little pieces and changes them without knowing the consequences for the totality.

From specialist to generalist

The division of the construction process into smaller and smaller pieces has led to the fact that more and more specialists are now participating. Each of them has the ambition of doing the best that he can within his part. We have specialists on, for example, high voltage and low voltage current, control and adjustment systems, media, elevators, etc. In the late 1980s, the organizational patterns therefore became more incomprehensive. For the future we will need very strong key persons, generalists, with the ability to look at totality and make their own judgements as concerns a suitable ambition and cost level for each individual project.

The many small and unique projects of the future will not have a higher proportion of design made by specialists. On the contrary, generalists having an eye for the project's common features will be able to simultaneously manage and design many small projects by means of efficient aids. Competition will be adamant.

From general contract to just-in-time

Endless discussions on the advantages and disadvantages of general and design/build contracts have concealed the fact that both are built on the same "linear" view. What is a design/build contract other than a wrapped general contract? The consultant still knows by experience that working patterns and delimitations in design/build contracts are just as traditional as in general contracts. In the first place, the most important difference

between the two refers to the relation with the purchaser and the power and control over the project.

What happens now is that the types of procurement are changing and that the element of parallel design and procurement increases. We will be drawing while the houses are being built. The element of tendering combined with post-tendering negotiations, own labour and organization contracts, target cost contracts with variable fee and split contracts will increase. All this aims at tailoring the project in terms of function and cost for each point in time.

Procurement and supply of building components will take place just-in-time to gain the best possible outcome. The site manager and the buyers participate in planning and design to prepare for production, instead of "redrawing" the project after finished planning and design and adapt it to the current production technology. The consequence of this is often that the architectural overall solution is being spoilt.

From turn-key delivery to simultaneous presence of the client

"If just a proper construction programme had been available" is a common remark when analysing in retrospect what went wrong in the process. This way of thinking means that people believe that the client can in advance formulate all demands on the prospective building. In reality, the demands successively develop during the course of work.

By participating in the work, the client has time to mature, realize the consequences of certain choices and can make qualitatively better decisions in various situations. Instead of striving to keep the client outside, we ought to design and produce in the presence of the client. To educate the client in advance for his participation in the various phases of

the construction process may be an important partial ingredient in future construction processes.

The educational situation will then be mutual. Architects and constructors must learn to understand the client's way of working and ordering to be able to produce the requested product. The client, and those who will use the premises, may take part in a much more efficient way if they understand the work of the construction industry.

The building's performance - from general opinions to systematics

In future the building's performance must be described to the client in the same way as the characteristics of other industrial products are described. The descriptions must be reliable. They must stand up against legal scrutiny in court. The building codes and loan directives which the construction sector has referred to earlier - and comfortably rested on - have now been efficiently abolished by themselves. And when it comes to responsibility, the local authority's compulsory building permit inspections is not worth a thing, in spite of the high cost we pay for this inspection.

With a ten-year-long liability period for the building and its performance, something entirely new is brought into the construction sector. From this it also follows that we who work within this industry must also settle our respective parts of liability and contribute in creating a construction process which can meet the new demands. Reference to and knowledge of European standards will be increasingly important to keep pace with the dismantling of the code system.

Alarming scientific reports revealing that approx. 30 % of newly produced buildings is in the danger zone of being so called sick buildings may make this a strongly guiding factor.

The sensible tenant's questions are justified: Is the flat healthy enough to live in? Is it a radon flat? Of what material is it built, what glue, putty, plastics, does it contain flammable material, can someone who is allergic to dust or is hypersensitive to electricity live in the flat? What proportion of consumed air is mixed with fresh air? Can it be guaranteed that the answers are correct? Can this be included in the tenancy agreement or is the product - the place where I live - used at my own risk?

It will be important for companies to document what preconditions and quality levels should be reached in the individual project to be able to show/prove that the companies have fulfilled their obligations. Among other things, it must be evaluated if the prescribed functional requirements have been met.

On the one hand, it is a competitive strength to be able to describe in a relevant manner one's products to the clients considering the new questions they will put. On the other hand, to be trustworthy, the companies must show that they have enough strength to take responsibility for their products. We must find instruments for documenting initially the client's demands and wishes as concerns the prospective building and thereafter transform this into concrete design proposals. These will then be documented and quality assured for procurement and construction. A great part of this information is reusable and in principle indispensible in the subsequent real estate management.

My opinion is that the ways of information handling in today's construction process are entirely insufficient. The aim and direction so far

is to document the building in a way suited to the construction production, while the description of the building's performance is in the background. To a much higher degree than before we must be able to describe the building's features for other purposes than for producing it. This new information handling will be very extensive both in terms of quantity and quality. Already today information technology offers various technical solution for handling it. Particularly the database technology could be utilized better than what has been the case so far. We do not have a lack of techniques. It is now more a question of how we choose to work in future, how we arrange a smart construction process which can cope with the clients' demands.

From prejudice to evaluation

To evaluate planning and construction proposals will in future be a delicate task. The decisions on financing will partly be made in other bodies than before, with banks and insurance companies. Based on the painful experiences of recent years, better financial calculations for real estate will in future be required where life-cycle costs and total economy are taken into consideration.

The local housing committees can no longer refer to national minimum codes when evaluating the contents of the proposals.

Not to make these evaluations haphazardous as a result of prejudices, new instruments for evaluations will be required. We will see proposals being evaluated before accomplishment as well as systematic follow-ups of the extent to which the houses meet the performance agreed on. In for example England, Denmark and the United States, methods for Post

Occupancy Evaluation are developed which prove that this is a feasible way.

The evaluations will also lead to more interest in synoptic planning than what has been the case for a long time.

For all those who are to evaluate construction proposals and thereby participate in planning the changes in the common urban environment, it is essential that they have an insight into what is the distinctive character of the town and thereby know or feel what is possible. They must be able to relate the individual construction project to the town's development as a whole.

For two decades, synoptic planning has had a bad reputation and has falsely only been seen as a method of being in control of other people. And a plan meaning a static picture of a future ideal state does not work, of course. A town is not a dead object and can only be understood over time. There exist pictures of ideal towns also from our time, but the total town is an impossible idea. The town may instead be seen as a number of processes leading to constant changes. I think we could talk about the town's cycle of operation and that the time dimension is what explains and characterizes the town.

To understand the distinctive character of a town means to pay attention to the peculiar and specific elements of people's activities, the history of the place and the town's culture as a whole. To a certain extent, it is a matter of imagining what people earlier thought and felt - what thoughts and feelings cling to the houses. It is also a matter of an analysis of the demands made by new activities and whether the town may develop by replacing certain parts of it, or if it may grow parallel with maintained identity.

The basis of modern synoptic planning should be knowledge about the demands for change of the actual activities as well as about the complicated build-up of relations which are influenced if the desired changes are carried out. By constantly keeping up such a knowledge of relations, it is possible in each single case to decide on the proposals for change in question at a specific time but which may not be foreseen now. The plan is needed as a starting-point of a dialogue and negotiations between representatives of differing interests, and it may help to round up such negotiations in reasonable time in relation to planned investments. It is also needed to give the citizens insight into, and influence over, the development of their society.

Planning is also needed for the ecology of the town. This concerns the relationship between landscape and infrastructure as well as the pattern and buildings of the town. It also refers to the relationship between people's differing way of life, their health and security, and the many different sets of rules which the individual considers to overlap each other in an incomprehensive way.

Information technology, particularly in the shape of so called geographical information systems, GIS, offers the tools to keep the necessary fact database up-to-date and accessible.

From taking a chance to quality assurance

Quality assurance is slowly becoming as inevitable in the construction sector as in all other industry. The experiences of the long checklists which are the first visible sign of quality assurance are not only positive. With quality assurance we could rather be referring to quality development and use methods to develop for each individual project the

most suitable solutions and gain experience between the projects. Mistakes should not be repeated over and over again just because it is more comfortable not having to think.

What has happened so far is that we have introduced quality assurance systems which should secure that we design and build the quality agreed on with the client, neither more, nor less. A battery of measures should control and document that building documents and construction products are of the right quality.

The aim is excellent because construction errors must be reduced. However, the conditions of the innovative element, the mere know-how development of the process have not improved. On the contrary, the number of routines and documents have increased without supplying the working process with new know-how on demands and possible solutions.

It is not enough with systems which see to it that incorrectly formulated demands are met. For example, if a ventilating system does not work it does not necessarily mean that the installation is incorrect. The reason may rather be that there is a lack of basic know-how, or available knowhow of what features must be involved to make people feel well may not be utilized. And the limitation of quality assurance is particularly evident if we try to talk about architecture and art of the right, predetermined quality.

Quality assurance of measurable characteristics is one thing, architecture as a whole is another thing. This does not mean that the framing aspects may be haphazardous. One way of escaping this dilemma is to make the regulations stricter as concerns the desired, measurable performance of the buildings and use sharp tools to control that they are

followed. The soft qualities can only be assured by creating a good design process, with close contact between client and planner.

From construction errors to coordination

In spite of all efforts, construction errors account for an alarmingly high cost and for the bad repute sometimes associated with this sector. Investigations point to the fact that half of all construction errors are the result of incorrect planning and design. But it is very rare that the individual professional makes mistakes in drawing or designing. A beam rarely has the wrong dimensions. To a large extent, the errors originate from lack of coordination.

In the strictly divided working process, everyone mostly does the right thing, but it lacks in totality. This speaks in favour of a much stronger integration between different occupational disciplines, and thus not just a few extra coordination meetings. And is it not remarkable that traditional documentation forms are allowed to live on? The architect and technical consultant make drawings with absolute precision while electrical and HVAC consultants work with schematic symbols and leave to the supplier to construct the increasingly complicated and voluminous installation plants. It is only natural that faults occur and leave subsequent disputes of who made the mistakes. The computer system has given us the right tool for starting to use a much smarter documentation technique.

From building document to project database

The concentration on producing building documents is also characteristic of the millon programme's information handling and today's way of working. All underlying classification and all directions serve a

description of the prospective building from a building production point of view. Sometimes the ambition is even limited only to producing a tender document. In future the development will be towards tools for design and communication with the client as well as new, forceful tools for efficient real estate management.

The tremendous amount of information built up in the project will be organized as a project database where users may retrieve information for most differing purposes. The principle aim of the project database will eventually be to serve the real estate management.

From aids to strategies for management

Management works with four variables: personnel, organization, economy and aids. It is typical of the development work within the construction sector to put the aids in focus. Of necessity, the interest is now being directed towards development of management, organization, and personnel strategies. The traditional construction companies have met competition from "construction management" companies who take responsibility for projects without having their own building workers. It is a matter of having the best competence to run the project and efficiently utilize many small niche companies in coordination, in order to produce the product demanded.

A construction and IT network

From addition of demands to parallel work and superimposing

All these new demands on the working process can, however, not only be added to the old ways of working. The process must be altered and the demands be superimposed. Computer aids in various forms will be required to increase productivity *at the same time* as the companies' products are quality assured in an economic way.

The linear process, where demands have been added and added and everybody has charged in percentages of as high as possible construction costs, has contributed to shooting up the construction costs. We will probably see a transition from these very high frame costs and index arguments to responsible and fixed prices. Certain strategists talk about halved production costs. The development in Norway 1987-92 is mentioned as an example of this development to be possible also in Sweden.

From relay race to rugby team

In my opinion, the image of the future construction process can no longer be that of a *relay race* with each person running his distance and much irritation coming up when handing over the batons.

The models can instead be found in innovation processes of other industries; "just-in-time", "lean production", "simultaneous development and production in constant presence of the client". We should work for a change from a divided to an integrated construction process.

The infrastructure of the construction process could be seen as a network whose nodes are the actors of the sector and where their function

in the ongoing project is the vital thing and not the traditional occupational or role division. According to the innovation researcher Bengt-Arne Vedin, simultaneous participation of all competences in a team, a *rugby team*, who fights to reach the goal is maybe a better metaphor for the future construction process than the relay race.

In a corresponding way, the individual personal computer is too limited a metaphor for information technology. Powerful working stations with their own computer strength connected in networks in and between companies will give an information technological infrastructure with entirely new options. The real potential is not primarily in the single computers but in the network uniting various kinds of know-how. It has now become possible to involve more competences *simultaneously* in the design and decision process, which is an important element of innovative activity.

The combination of a network of cooperating actors in the construction sector and the communication possibilities of information technology gives the contours of a smart construction process which permits parallel activities.

In the vision of this new construction process we also see that guild-like occupational limits are dissolved, that large geographical distances are no longer an obstacle and that national border-lines can be crossed.

2 INFORMATION TECHNOLOGY

Information technology, IT, has given us an opportunity to efficiently manage large amounts of information. IT gives the construction sector companies access to tools for design and cost-effective planning and design, building production and real estate management of high quality.

They can now make cost calculations starting from the early stages and control costs throughout the whole production process. They have the tools to save and reuse good solutions for new projects. They can search in databases to find information on national building regulations and standards, and they can search among building materials and suppliers in Sweden and abroad. They can quickly solicit tenders and make deals electronically. They can simulate the building production and the building-site organization in order to plan for efficient production, quality assurance and safe working environment on site. They can offer efficient forms of strategic real estate management. By means of advanced visualization, they can beforehand show their clients what a construction project will be like and sell their solution.

However, to achieve the advantages which this technology implicits, the companies must take the step from just using computers as detached, electronic pens to seeing them as parts of an infrastructure for efficient information handling in the construction sector.

The application of computers to handle large amounts of data has become the model of our time to better organize working processes of the most varying types. If the ideas of a desired work organization have called for the new computer aids, or if, on the contrary, information technology has opened our eyes to new ways of thinking, I will leave unsaid.

The IT building confusion

Right now we witness the introduction of IT into the construction sector. Therefore, it is difficult to correctly describe what is happening. Some distance is needed to be able to observe and interpret it in the right way. But just as the insight into the *principles* of mechanization led those who tried to depict the future during the 19th century to partly true predictions, our knowledge of the principles of information technology may give us possibilities of looking into the future.

The concept of information technology is used in many contexts and often with different significations. It is a matter of technologies to handle information. However, this is not enough to close in the signification of the concept. A book is an excellent information carrier, but it is not a piece of information technology. On the other hand, information technology is used for the production of the book - from the author's word processor to the computers of the graphic office for type-setting and graphic design. The colour separation of pictures takes place in computers and the printing process is controlled by computers. Computers are used for distributing the book, and the readers can find it by searching in databases. The reader notices the presence of information technology in

no other way than that, thanks to the computers, the price of the book is still reasonable.

Technology is more than a technique. There are many different techniques involved with a common denominator, and the word technology has a promise of future and development in it. Common to all kinds of information technology is that some kind of computer application is used. It may be anything from a complete computer system to a hardly visible memory chip. With this wide definition it is obvious that information technology is rapidly increasing in almost all areas of society and that we daily use it in the most differing forms. We unlock the door, pay our bills and start our car with it.

In the construction sector, the concept is also used in several contexts. Different occupational groups think of different things when they hear about the reforming influence of information technology when it comes to drawing, constructing and manage houses. The scope is very large. IT is everything from abstract model building in design, called product modelling, to the use of computerized robots on building sites, which can walk the stairs and carry out jobs which are dangerous to human beings. The IT concept comprises the technological systems - computers, networks and surrounding equipment - as well as their application in the information flow which the construction process makes up. It is also used to describe the partly new contents of future buildings; "the intelligent house" whose technological systems are computerized.

Information technology is also involved in urban planning. Geographical information systems gain a footing there and they store co-ordinated facts which are necessary prerequisites of design and construction.

In a corresponding way, the information created in design and construction is expected to be revised and reused in the management stage for planning of operation and maintenance.

While CAD, computer aided design, has become a relatively common element in building work, both GIS, geographical information systems, and FMF, facility management systems, are new and to many they are rather unfamiliar applications of IT. They have however a very large potential, at least as large as that of the CAD technique.

There is only an apparent concensus as regards the concept of IT in the constrction sector in the wide signification of computer based information systems in urban planning, design, construction and management, and for certain technical installations in buildings and plants. With this somewhat unreflected idea of the IT concept there is a risk that all computer programmes, computers and conceivable applications in the construction process will be considered as important and worth attention. To be honest, this is what has sometimes happened. Each form of high-tech has motivated its particular articles, exhibitions, study trips and conferences with their reports from evaluating trade organizations.

The concept is too general to be a guidance for strategic thinking, whether it is a matter of an IT strategy for a construction or architectural company or a programme for research in the area. Let us apply three different views on the application of IT as a basis for the discussion to follow.

The tool perspective

Computer systems are regarded as tools among other tools and are used for the limited tasks they are considered to be best suited. In this opinion, manual and computer aided work may preferably be mixed in a company, or even in the individual project.

In this view, the traditional working process is not changed in a decisive way after the entry of computers. Only certain working elements are renewed and the time efficiency of work is marginal. Different actors may use different computer systems with different application programmes, operating systems and user interfaces simply because they exchange data only to a limited extent. For obvious reasons, much interest is instead devoted to comparing between them different computer systems as well as advantages and disadvantages, similarities and dissimilarities between manual and computer aided work.

The information flow perspective

This view emphasizes instead the information flow of the construction process as the most important thing. It should be possible to use the information in various phases. The different actors' demands for information and their presentation are mapped. Computer systems are expected to supply the actors with what is called the "right" information on the "right" occasion and presented in the "right" form.

Earlier it was believed that the trade would be able to come to an agreement on an individual computer system which would for a long time to come be the most suitable. Of course, this turned out to be a barren way of introducing computer technique, the development and standardization of so called transition formats between different systems is now

emphasized. People are now prepared to renounce the individual user's specific demands in order to make the information flow function as a whole.

The product model perspective

Here the product model is pointed out as the core of the process, i.e. the logical structure in which the prospective building is described in a computer.

The thought is that if the product model is ingenious enough, the actors themselves should be able to collect information from it. They should also be able themselves to choose how to further process and present the collected data. If by international standardization an agreement can be reached on the principles of product modelling, the user can freely utilize the computer system which gives him the best support for his occupational life.

The interest is displaced from the apparatuses and their performance to issues of, among other things, the representation forms of architecture and classification and structure of building components. Anyone who has followed this development for a period of twenty years can observe a shift over time of the interest from tool perspective via information perspective to product modelling. This is also where the research front is at present.

Research on IT in the construction sector

With the purpose of relating the Swedish contributions to the international research front, a special expert group within the Swedish Council for Building Research (BFR) has presented a programme for research on computer aid for design, construction and management. This will be of

help to those who want to inform themselves about how the researchers think and how far they have reached. The group's task has been to formulate a programme for BFR on this subject field. Another reason has been to make ongoing research in this field more efficient as it earlier "postponed everything" as a result of what I have called the IT building confusion.

Since 1990 BFR works according to this programme. The first IT building conference in December 1990 was the take-off of a large national research concentration on IT in design, construction and management. This is financed by BFR, the Swedish Council for Building Research, NUTEK (the Swedish National Board for Industrial and Technical Development), SBUF (Development Fund of the Swedish Construction Industry), and SABO (Swedish Association of Municipal Housing Companies). The total research budget is approx. MSEK 70 divided into six financial years. The research is carried out in special centres at the three universities of technology in Stockholm, Gothenburg and Lund. Researchers as well as planners, constructors and real estate managers are engaged in the local reference groups.

After these results had been archieved, we in the group suggested that it should be reconstructed and work with a new scoop, i.e. the future design, construction and management process. We meant that IT issues had to be connected to the construction sector's development as a whole. Otherwise, their importance was running the risk of being reduced to the category of smart aids.

One principal thought behind BFR's programme is that research in this area must be in harmony with development in the construction and computer industry, respectively. Above all, governmental building

research should contribute to finding a solution to matters of common interest to planners, constructors and managers. Product modelling plays a central part in the research programme. Its possibilities and possible limitations must be investigated.

Can the information be organized to be useful in practical and financial respects throughout the whole process and independently of special computer systems? It is important to develop methods for classification of building components and information structuring in order to send information between and interpret it in the different systems of the participants. Prestandardization is a strategic area, between research and the international standardization negotiations necessary for construction companies and the materials industry.

A concentration on IT is expensive and must take place in cooperation between the financiers concerned. In the cooperation between BFR, SBUF, NUTEK and SABO which has now started, the programme of BFR points to the fact that the early and late phases of the process must be observed in particular. So far, the phases before design and construction as well as the different parts of the management work have too much been outside the researchers' interest.

How is the construction process supplied with landscape information and co-ordinated facts about the infrastructure? Attention should be paid to the connection between GIS, geographical information systems, and product modelling. The information demands of the management phase must be described before it can be computerized. This also refers to the question how information can be best accessible in modern, decentralized area management. From the client's point of view, the needs of the early

phases of clear documentation, visualization of what has not yet been built, and simulation of various consequences are also important.

When BFR so strongly stresses the client perspective, this should be seen in a wide sense: owner, user, manager, and operation and maintenance personnel. The perspective is a complement to the direction so far of design and construction. These areas still hold a high development potential for increased capacity, cost cuts and quality assurance through computer aid.

Parallelly with the development of these applications of the new technology there must be a critical scrutinization which controls that the concept formation is always kept up-to-date. Research is needed which describes the consequences of bringing new technology into old professions. Knowledge of this kind is also needed to reach an understanding of how future computer systems should be arranged and adapted to the demands of different occupational groups. The technology romanticism which thrives abundantly must be balanced by research on the relationship between the human being and the machine.

Based on a review of the development areas, the programme points out ten research areas of particular interest:

* *Knowledge based systems*
* *Graphic data processing (with emphasis on interaction and the user's competence development, above all CAD)*
* *Concept development and concept formation in the area*
* *Design theory (know-how, competence, and learning issues of design work)*
* *Hypermedia*

* *Visualization*
* *Product modelling (with emphasis on integration of design-production-management)*
* *Computer aid in the production process*
* *Computer aid in the management process*
* *Geographical information systems*

The areas which BFR ought to concentrate on and do peak research in are:

* *Product models*
* *Knowledge based systems*
* *Visualization*
* *Geographical information systems*

With centres for IT at the universities of technology in Stockholm, Gothenburg and Lund, a good form of technology distribution has been created. The trade can turn to the respective center to be concretely acquainted with the new technology. At Chalmers University of Technology in Gothenburg, for example, an "Application center" has been established where the new technology is demonstrated. Experience can thereby be spread more quickly to the practicians than what is the case if only the most necessary reports of scientific research are relied on. The IT building research has only just started and it remains to be seen what actual results will be achieved by researchers.

One positive side of a research programme of this kind is that the problems originate from practical life and are translated into themes of research. However, it is not easy for the practician to see the benefit of

research within each segment. Even if researchers are induced to work with a problem picked up from the world of practicians, they report in the first place back to the research world. This is the world where they make a career. There are other researchers who judge the scientific quality of their research and if it is good enough to qualify for a doctorate, associate professorship or professorship. This is why practicians must take an interest in the results of research, take advantage of them themselves and transform them into their own work. This task is inevitable and can never be replaced by educational advisers or compendia with amusing illustrations. There must be researchers and technology transfer also in the companies.

Among other things, it is a matter of understanding what kind of know-how is produced by research. Let us take BFR as an example. They contribute to research which produces at least four different types of know-how. First, *facts* about the buildings, their extension and use, their technical condition and energy consumption. With these facts as a basis, we can plan for future changes. Secondly, the kind of research and development which results in *technological innovations*. This gives us knowledge of new building materials and production methods. Thirdly, development of new administrative *aids* for planning and design, e.g. IT aids. Lastly, the kind of know-how which helps us understand *development trends* and which describes the coherence and patterns of what is happening. It gives us concepts to discuss what may otherwise be felt as incomprehensive or even chaotic.

In his book "Planerarnas århundrade" (The century of planners), the architectural historian Olle Svedberg (1991) deals with the architectural history of our century. He describes the planner's pictures of the future

and visions of planners and the houses and towns of reality. To a large extent, the contrasts are tremendous, among other things between the hopes given birth to by the achievements of technology and our restricted ability of applying the technology in an entirely correct way. It is also about the individual's dream of living in an everyday paradise in a society with ecological balance and our restricted ability to make it real.

According to Olle Svedberg, one of the characteristic traits of planners and architects is that, more or less consciously, many of us want to combine two things, i.e. utilize far advanced technology to build well functioning, beautiful and healthy buildings. Architectural history is a means of understanding the development course. It can explain the intentions of what has been built and give us instruments for bringing our thoughts into order and understand what is happening now. The words of an architectural historian are worth considering, not least right now when the working methods of architecture and construction are questioned. A new technology is exactly what we hope for when we try to improve the way of drawing, constructing and managing buildings.

Therefore, a special subject of research is to find out if construction and technical consulting companies are able to "rebuild" themselves, to seriously and fully make use of the new technology and thereby approach the future in a responsible manner. To what extent is new know-how brought in and applied into company organizations? And how are the companies organized in terms of R&D work? What does research mean to the managements of the construction industry? To what extent do the companies develop their own organization so that it can make use of new know-how originating from research?

IT to the benefit of the residents

The reader of a book does not notice the presence of information technology used to produce the book. Will the residents notice that IT has been used in the construction process? Is IT development required for the benefit of residents?

Bostadsbolaget is one of the major public housing corporations in Sweden and their development department is now taking an interest in the possibilities of computer technology for practical real estate management. The reason is obvious when considering the following facts: 15 per cent of Bostadsbolaget's approx. 30,000 flats change tenants every year, i.e. approx. 5,000 flats are offered for rent. Before a tenancy agreement with the new tenant is signed, approx. five households have shown interest in the flat. This means that, only for the purpose of lease, Bostadsbolaget has had to give out information 25,000 times in a year.

Someone interested in a new flat wants to know what it looks like, what size and what layout it has. Frequent questions are: What standard, equipment, and materials does the flat have and when was it last repaired? Where in the area is the flat, on which floor, what about parking lots, playgrounds, public transportation, and service? What does it cost to rent, what is included and how is it calculated?

Altogether, these in themselves simple facts - data - are many in numbers and are to be presented to 25,000 different recipients on different occasions during the year. In addition, the contents of these data are changed from time to time. It is a matter of different kinds of information, both text and drawings. Several persons in the company hand out these data. The information must be reliable as it is the basis of an agreement.

Now the tenant has an additional question, if the flat is healthy enough to live in.

What looked in the beginning like a quantitative matter, to be able to handle in a practical way a very large number of simple facts and supply them in a simple and economic way to the clients, is turning out to be a very delicate qualitative task. Of course the clients' new questions are in the highest degree justified, but they are difficult to answer. Facts about building material and risks are spread in many places and difficult to get hold of. Nor are the facts always enough to give reliable answers to all the questions. Furthermore, researchers and producers do not yet have a clear view of all causal relationships involved in what is called sick buildings. But the questions are put.

It is evident that the construction process must be supplied with more facts about human needs and the qualities of building materials. Intelligent use of computers may come to play a significant role in communicating these qualities. The knowledge is often already there but not used as it is not accessible in a comfortable manner. Errors are being repeated because there is a lack of systems to pass on the experiences.

Research and development of computer use in the construction industry must be directed towards making knowledge accessible so that the construction industry can solve their major problems and come up to the expectations by the world around - functional, safe and healthy buildings.

More emphasis should be placed on how to get access to and present existing facts. Therefore the computer systems of the future for architecture and construction will rest on a connection between hypermedia and intelligent CAD. Behind such systems is the desirable

insight into the difference between information stored in a computer and knowledge living in a human being. To handle large databases of empirical data, the KS technique, Know-how based Systems, may be used.

To quote Olle Eriksson (1991), it will be a main task for an information system built on IT to describe to the planner what it looks like in the manager's empirical bank.

3 COMPUTER AIDED DESIGN

Information technology, in the shape of administrative and technical computerization, holds the possibilities of a new structure in the construction sector. It enables a flow of information through the networks which will in future connect the actors of this sector. But what is the benefit of computer aid in architecture and design? What are the possibilities of information technology in the core of architectural work? Is it even an obstacle to the searching sketching process? There is a simple reason why architects ought to benefit a lot from computer aid in the mere design work. In their drawings, they organize very large amounts of data and drawings are changed again and again.

Drawings as carriers of information

On my way to work in Uppsala I pass the university's main building from 1887. It is an impressive building which expresses in every detail the ideals and conception of scientific greatness of that time. The building's architecture belongs to the classicist tradition. Here we find tranquility and perspective, symmetry and decor. Icons, ciphers and inscription plates are all over the building. It is an "architecture parlante" - a talking building.

The building was drawn by Herman Teodor Holmgren and was documented in no less than 332 detailed drawings. Drawing number 332 refers to the loose floor of the assembly hall's scene. The drawings served several purposes. They showed the craftsmen how to build. The were also used for cost calculations and in discussions and negotiations in the 261 meetings between client, constructor and architect of which minutes were kept. The beautiful drawings reflect the architect's intention. The documentation technique in itself is in accord with the building's architecture. The information in the drawings is of a such high quality that it can be transformed into live knowledge with the reader.

Holmgren was an architect with classical education. The university is his great contribution to Swedish architecture. For the classically educated architect with his tool box of good solutions and his well developed documentation technique it "sufficed" to be a very skilled craftsman. For a functionalist it was required to be an artist to produce architecture of the same dignity.

Sketches for vivid realization and participation

Let me take another building as a basis for reflecting the possibilities of using computers in architectural work.

A hundred years after Holmgren, Peter Celsing makes a proposal for a new university building in Uppsala, Humanistcentrum. He suggests that the building be placed next to the Botanical Garden below Uppsala castle. In a little A4-size pamphlet he shows the building in sketches over the general plan, building plans, facades, sections and a series of perspective drawings.

The sketches are extremely "simple". The facade sketches are in the scale 1:2000! The perspective picture of a classroom may seem to be the result of playing with geometric basic forms. The room cube and globular shape of lighting fittings and terrestrial globe, the apple on the teacher's desk, her ample curves. In the exterior perspectives the building, which is large by Uppsala standards, disappears among the trees of the Botanical Garden and interplays with the clear air space of Uppsala in spring and autumn. These indicated shapes and "unfinished" images are supplemented by the reader's own fantasy. They invite you to vivid realization and interpretation. The reader is being part of the prospective building and is on the architect's side. This is a clever way of using a sketch as a medium to illustrate, convince and invite to participation.

Celsing was more than a functionalist. He was a poet exceeding functionalism, according to Ulf Linde (1980). This can also be experienced when visiting the building Humanistcentrum which was later built on another site and in another scale. Like a Venetian palace, but built with white and gold-ochre coloured, pre-fabricated concrete panels, the building has its natural location on the Luthag field.

Two kinds of pictures: the sketch to illustrate and convince, and the drawing as a basis for agreements and for building. However, there exists another type of pictures in architectural work.

Tools used to get a clear understanding

Many of the pictures made by an architect in a project has the purpose of investigating a problem and they contribute to giving the originator himself an understanding. The pictures show how the architect has "tasted" the job and searched to find the patterns where it could fit in.

Work in the sketching phase does not mean, in the first place, that problems are being solved. Instead, the client's order is split *up* to see what the task actually consists of. If we ask the architect about the contents in the sketching process, he will answer that he knows *what* he does but that he cannot describe *how*. If we insist on an answer the answer may be that "the know-how is in the pen". We can notice an interaction between pen, paper, hand, eye, brain. The resistance of the paper gives me the time I need to think, is a comment sometimes made. The computer is not considered to give that feeling!

The student of architecture is trained to depict architecture. In this way, he or she builds dimensions and proportions "into the pen" in order to later be able to express his/her own architectural ideas in images and in this way master the empty paper.

Images for communication and decision

To visualize is to make visible what has not yet been built. Based on a mutual conception of the prospected project, agreements are made on its economy and disivion of responsibility between client, planner, contractor and manager. This early conception or "mental" image, which is sometimes made concrete in simple sketches, is successively added on during the course of project work. From having initially been an idea or a concept, it is transformed into complete technical documentation in the form of drawings and descriptions - a recipe for building the structure. In its turn, this recipe must also be instructive so that the local manager, overseers and building workers can build with the correct, high quality.

To a large extent, the work consists of a communication process in which the images fulfill the purpose of expressing ideas clear enough to

be understood by the participants and allow an agreement on what is to be built and how. To plan a project means working step by step towards an increasing degree of details. Typical of this work are the many revisions which are due to the fact that it is successively made clear to the participants what the prospective building should really look like. This insight can only be achieved by working on the project. The trick is to capture and make use of the increasing knowledge.

The simple sketch has here a vital function. It is immediate and direct, it shows how I think and I can quickly make changes in it, show it to others and have reactions and viewpoints which will improve the project.

There is a large number of image types to choose among, a tool-box filled with tools to express a project. Look at the architect's table! There you do not find just pens and paper, but many pens: lead, Indian ink, spirit ink, coloured pencils and water colour, and paper with various gray shades and grain. Here you find work models, material and colour samples, and instruments like camera and model periscope. The copying technique has developed fast and video technique and computers have now become additional "pens" to be used where they are best suited. It is a central matter for the architect's profession to be acquainted with all these tools and an important part of the total know-how offered by an architectural company. To be able to produce the very best images of each type, the professional architectural company has access to specialists.

The images are used in various combinations to be able to explain in sequences the many complex aspects of a project. The eye-level image shows how a new building can be comprehended when approaching it by foot, car or train. The survey image, from a low bird's eye view, gives the

reader an opportunity to acquaint himself with and understand how the building or plant is organized. The water-colour painting depicts how light falls over the building while the technical cut, the section, through the building helps us understand how it works. The simple sketch indicates how the building's architecture may be understood while the life-like and detailed photograph montage accounts for the exact conditions. The plans consist of image series showing how the project can be extended step by step.

The images are thus important tools in the artistic work to create a well functioning and beautiful building or plant. They may express shape, colour, material, texture, light and total effect and how the building can be experienced by different users in different seasons and time of day or night. However, it is at least as important to show how the building will change when ageing and its diversified use for future purposes.

The architect is not the only expert in a project. Comprehensible images are needed also for the expert group's internal work. The group analyzes the problems by means of sketches, drawings and models and alternative proposals emanate. The images are needed to describe positive and negative consequences of various proposals. As large, complex building tasks engage experts of various kinds, a metaphorical language is required which can be interpreted and used by occupational groups with very varying backgrounds.

It is easy to be fascinated by the way architectural drawings and perspective sketches are drawn up. During certain epochs they have been pieces of art in themselves. Today it happens that architectural drawings are exhibited and sold in art galleries. However, this is a very rare

phenomenon. In the first place, the images are aids in a working process aiming at creating architecture, not images of architecture.

The electronic pen

Can know-how "sitting in the pen" be computerized and what would be the advantages? This question is dealt with in a rich flora of articles, conference reports and books and it is the subject of dissertation work in architectural schools in various countries. However, it has not been answered by this.

It may be interesting to study how the computer industry probably went about when they wanted to introduce computers in architectural work 10-15 years ago. In short, it can be said that it all went wrong.

Probably, they believed that the core of the work was to make perspective drawings and to produce a large number of detail drawings. It is logical in a way, because this is what you see if you visit an architectural office. Therefore, systems were developed which would support the production of drawings in the late phases of work. Unfortunately, the systems were also very expensive. It was not taken into consideration that most of the final design decisions were already made and that several versions of hand-drawn sketches and drawings with the same information presented in different scales and with various degree of details already existed.

Of course, it was also expensive to load the computer with all information which was already manually recorded, in order just to produce detailed drawings, particularly as the architects were expected to present them on paper to clients and constructors. However, some of these

systems are still in existence and still discourage many people from using modern tools.

The same thing happened to the visualization programmes: they were too much focused on this very exclusive presentation of decisions already made. This type of presentation mainly aims at convincing clients, users and decision makers of the advantages of the finished proposal. The traditional architectural presentation - the perspective sketch - was the model of this type of computer aid. The computer programmes were designed to make the images as realistic as possible, but what is shown is often bare, rigid and insensitive. They require much computer power and are therefore time consuming and expensive to produce. In themselves, they are the result of impressive, advanced programming, but they do not communicate the architecture of the building or the ideas behind.

The images preferably used in the early sketching phase are, on the contrary, often soft, handmade sketches. We know by now quite a bit about how laymen read, understand and misunderstand common detailed plans and illustrations. We also know how to present them in a clear and comprehensible manner. It has proved to be important to be able to make choices, present images of various alternatives and to convey human intentions.

It is thus more important to find methods of creating images which stress what the architect wants to show than to make photo-realistic reproductions!

The architect begins with an empty paper. The clients, consultants and decision makers want the architect to make a proposal quickly, they want something to start with, a basis for calculations and discussions, and

they believe that if time is strictly limited, the architectural work will be cheap! Take the wide pen and the thin paper and make a sketch!

However, it is very important to understand and respect the complexity of sketch-work. It is schematic because work goes on simultaneously at so many levels. The approximation of the soft line is necessary. It makes it possible to make various decisions in various phases, for example to decide on the exact shape of the wall much later than when its location is being decided.

Here we have a decisive difference between the commercially available CAD systems: certain systems force the architect into making decisions too early. This leads to the fact that a detailed model of the prospective building is developed too early. It is then expensive and difficult to make changes. Other systems are open and allow step-wise defining of the model. This is important as the planning and decision process cannot be compressed more than to leave space for a human maturation period - to enter into and understand the consequences. The continuous changes are not a sign of bad discipline, they are part of the sketching process and they constitute it.

The architect makes the most important decisions of the whole project when he decides which of all conceivable aspects should be guiding the project in the next phase of work. Björn Linn (1983) has pointed out that certain facts come into focus and others are pushed in the background. Are the right issues and facts considered and available on the right occasions? What is the quality of facts used? Are there methods of widening the problem analysis and use more facts?

One possible way is to use systems based on know-how together with CAD systems to be able to expand the human intellect in the sketching

phase: an intelligent CAD system which can help the designer to find relevant facts in different databases or to analyze and describe the consequences of different aspects.

Dangers can be seen when the sketching process is computerized in the wrong way round. If the product specification comes too early in the process, the architect will have to work with the wrong issues at the wrong time. It is important with continued research on project modelling, but in parallel we must have theoretical research on the contents of the architect's profession and how know-how is accumulated in the sketching process. This will hopefully give us a better basis of formulating the designer's demands for new, useful tools.

If my criticism of the limitations of commercial CAD systems in the sketch work is justified, why have they still had this quick success? Well, this success for architects using CAD was late and relates to the technology of personal computers. In the mid 1980s, these small computers were powerful enough to deal with the large amount of information which a drawing could contain. In 1985, the first Swedish CAD application for personal computers for architects, ArCad, was introduced.

Two conditions have contributed to this quick success:

Firstly, personal computers made it possible to develop CAD as a *personal* aid for architects and designers and it strongly reduced the investment costs for the companies. Earlier they had been relying on computer power distributed via unintelligent terminals. The response time varied depending on how many were simultaneously using the common mainframe or mini computer. This was irritating, and you felt you were being watched. Others owned the computer you worked with and it was

unclear who had the copyright of what was stored in the computer memories. Shift work was needed to give economy to the high computer investment. Altogether, this made the prerequisites of creative work poor. The small personal computers represented another idea of occupational contents and became very attractive after they were loaded with powerful CAD applications.

Secondly, the personal computer aid *immersed* into the traditional, manual working process. Personal computers were used for exactly what they were then suited for. Manual and computer aided planning was also mixed in the same project. The computer was an electronic pen to be used together with traditional tools. The disadvantage of this is of course that planning work has only to a limited extent become more efficient. To make use of computers for design will be a much greater and even more meaningful challenge.

Computers for design

Not until the CAD systems can support the heart of architectural work, the sketching process, will they be wholly accepted by professionals. It is not until we have access to CAD systems which understand architects, according to Aart Bijl (1983), that we can use them as part of the necessary renewal of the whole process leading to a new building. To work out CAD systems for the sketch phase requires knowledge of sketching and design work. And this knowledge is not easily accessible. However, development in certain architectural schools is very promising these days.

Let us visit a few architectural schools in the USA in order to make observations of present development trends. It is obvious that while in

Sweden we have devoted much interest to computer aids for planning, in the USA computer systems as design aids have been developed.

A suitable start is *Cornell University* in Itacha where Donald Greenberg works. Since the early 1970s he has led the development in computer graphics. Already in 1974 he published a series of computer drawn colour illustrations in the Scientific American magazine. The pictures illustrated a planned, and later erected, museum of art on the university campus, drawn by I M Pei. His point was that the Renaissance's rules of perspective construction could be handled by computers. The illustrations were very striking. The fact that they were shown in sequences also contributed to this. His laboratory can now produce life-like, photo realistic computer images of very high quality. He can handle colours, textures, material qualities, light and reflections in his computer models. Above all, he has advanced far beyond the often hard and insensitive metaphorical language which we associate with computer graphics.

The architectural school of *Carnegie Mellon* in Pittsburgh is an example of another development. Among other things, they here work with AI techniques, artificial intelligence and expert systems. They do not restrict themselves to reproducing good architecture in a life-like way. Instead they want to use the computers to make proposals for good solutions. They insert expert know-how into computer systems. By posing questions like "if-then", the architect works interactively with the computer programmes to have support for describing advantages and disadvantages of various solutions. Not very humbly, but very successfully, the researchers have tested if various well-known buildings

can be considered to be well designed according to the criteria of their programmes.

At the *University of California* in Berkeley outside San Francisco they work with, among other things, calculations and simulation. There is a law in California saying that a new building must not shade existing houses. This has been the starting point of research that has resulted in well working systems to exactly show in advance how the shade from a building not yet built will fall at different points in time. Here the town landscape and houses are *modelled* in solid models. These are illuminated artificially in sequences showing light and shade at different points of time.

The interest in modelling a building is worth attention for us in Sweden who mostly use computers to produce two dimensional drawings as reproductions of the three dimensional model we have at best in our minds.

At the *University of Michigan* in Ann Arbour, they have since the 1970s and under Professor Harold Borkins developed computer aids for design. In their systems, they can directly sketch three-dimensionally. After creating a model of the intended building, they mark what horizontal and vertical cuts through the building they want to have drawn as constructional drawings. Via a tabular interface to a database which is connected to the CAD system, the architect indicates what building components he likes to use: types of walls, doors and windows, interior details, etc. The computer then makes the requested drawings automatically. To a large extent we often work in an opposite way in Sweden. We "draw" drawings with computer aid. These are then joined to perspective pictures for presentation.

This way of thinking has led to the development of sophisticated, but very inexpensive, specific design programmes. Professor Bill Mitchell at the *Graduate School of Design*, Harvard in Boston, shows how aids of this kind is a natural and integrated part of architectrual education. In a way corresponding to how we earlier learned to see a building, by making a sketch of it and thereby understand how it was represented in a drawing, his students now reproduce and analyze good architecture by means of computers. Not until then can they fully realize how the computer can be used to create architecture. Here they educate students in using computer aids for design, but also in programming to make the architects really understand the character of their new working tools. Certain students go further and train to be designers of new computer systems for architects.

CAAD has become a new common denominator for many architectural schools around the world. Computer Aided Architectural Design is now seriously being introduced as a new subject. It does not happen without resistance and conflicts. Resistance comes not least from teachers who may feel anxiety about the new technique - that they do not command it and that it is difficult to foresee how it will influence education as a whole. It actually still happens in Sweden that teachers threaten to reject students who use CAD to make a fair copy of their planning/design sketches. However, threats of this kind do not have the effect intended. Instead it stimulates to an increased desire for experiments among the students. The technique also creates conflicts because it is expensive and requires an entirely different size of investments as compared to what has been customary in the schools. However, both students and practicians expect of course that the schools

do research and educate in this area which has become so important in practical professional work.

The new and young groups of teachers and researchers in CAAD in the architectural schools in Europe and the USA have each created a forum for exchanging experiences and ideas. ECAADE, Education in Computer Aided Architectural Design in Europe, is the name of the European organization. ACADIA, The Association for Computer aided Design in Architecture, is the American one and as indicated by its name, it is open also to participants from other countries.

When ACADIA held its yearly conference in 1990, it was the tenth in number and the subject was significantly "From research to practice".

The meeting between practicians and teachers was informative. The architect Terry Poindexter of *Skidmore, Owings and Merrill* in Chicago presented an overall account of how they had integrated architecture and technique. He showed how they used their own CAD system, AES, which is the fifth of SOM's CAD systems developed by themselves. The system does far more than produce drawings. The computer model of the prospective building created in the system is used for analysis and calculation, simulation of loads, air streams etc. and for very advanced visualization. Among other things, it is also used for quality take-off and real estate management. Poindexter talked less about the CAD system itself and more about "information management" for the whole company. The earning capacity is in reutilization of data. He stressed three characteristics in particular of SOM's AES system: the connection between graphic information and database, the integration between the different disciplines of architecture-statics-HVAC-electrical engineering

etc., and the application of systems based on know-how for, among other things, construction of stairs.

None of the architectural schools could present an activity which wholly corresponds to what the practician requires. However, the many angles of incidence and ideas present were very inspiring and thought-provoking.

One session was devoted to conceptual design and the signification of the design concept. Can by advanced visualization the architecture of various buildings be made visible and comprehensible to the students? By means of "Image Sampling" architectural images were scanned from books and journals. These were combined with digital images from imagined building sites and the students could in this way see how various design concepts were expressed. The technique is very simple to learn and use. A kind of electronic pattern book, which is maybe too biased in stressing the exterior design of the building.

A presentation which was more firmly established in architectural theory and history was "Of Computer Memory and Human Remembrance: History of Urban Form Through Three Dimensional Computer Modeling" by Thomas Seebohm from the *University of Waterloo*, Canada.

CAD techniques were used in the architectural history education. The students were themselves allowed to "reerect" (computer) models of whole cities and simply revisit cities which no longer existed. Thomas Seebohm gave an example of how the teachers had provided a computer model of a landscape in which the students were to reerect the ancient fantasy city of Xara. Here is the harbour, boat houses, market place and houses by the sea. Acropolis with its many temples rises on the hill in the

background. Here is the meeting place, the agora and the amphitheatre. When the computer model was ready, it contained no less than 500 buildings. It would not have been possible for the students to build this city as a wood or paper model.

Reading to get an understanding of the structure and elements of the ancient city and its location in the landscape cannot give the same vivid realization as with a computer having modelled a whole city in detail. With this understanding of the structure of the ancient city, the students are mature enough to draw parallels with the modern city. All architectural history is contemporary.

Thomas Seebohm also used the computer to analyze an architectural fantasy which only exists in pictures: "Deconstructing the Constructivist Drawings of Iakov Chernikhov". Seebohm wanted to know what the plan and three dimensional forms look like in that which Chernikhov showed in one single perspective drawing. As Chernikhov taught perspective drawing and washing, he ought to have had a consequent way of constructing his perspectives. With computer aid, Seebohm could analyze a number of imagined observation points for Chernikhov's perspective and thereby a number of relative positions and proportions for the building and its parts. He could thus deconstruct Chernikhov's perspective drawing into the three dimensional forms which it is intended to reproduce.

It then turned out that his architecture was more an illusion than buildable reality. The architecture expressed in pictures can only be seen from one single point, and then the plan picture is not in agreement with the perspective either. Chernikhov changed the proportions of the picture to bring out his idea. Built in reality, they would look different.However,

what is more interesting than this to many architects well known characteristic is that we here have a method of studying architecture which is only preserved in pictures.

In principle, however, I am critical of the clinical way of approaching the architectural picture. How can we actually know how the architectural idea is best described in a picture? The two-point perspective is not the whole truth. However, studies of this kind show with what form vocabulary the architect works. "Shape Grammars", accidence in the literal sense of the word, dissects the building into its different form elements and their spatial connections. This subject is in great favour in American architectural education and is perhaps the reason for the success of the CAD subject there.

The distance is not long between "Shape Grammars" and "Component Based Approaches in CAD". The thought is that a building consists of well defined components which can be described three-dimensionally and stored in libraries. The components can be combined according to the rules of the theoretical and applied aesthetics used by the architect. With this approach, certain architecture is becoming more interesting. Therefore, analyzing a villa in Palladio by means of a computer is now quite understandably the basics of CAD education. In Sweden, Gunnar Asplund's buildings should be in a favourable position for practices of this kind.

Leandro Madrazo, *Swiss Federal Institute of Technology*, Zurich, made the most sharp-edged presentation in the conference on the theme 'component-based CAD'. As long as the computer model of the prospective building consists of only lines, the architect cannot develop alternatives, nor test various solutions. However, if the building can be

divided into 3D components and the system recognizes these components, general commands by the architect may result in component changes. This is actually the only way that CAD systems can be efficient sketching aids. Madrazo is a researcher but he has also worked at Skidmore, Owings and Merril in Los Angeles. He presented a series of stunningly beautiful pictures which he had created with the help of SOM's AES system. With an advanced CAD system, it is possible to achieve the desired connection between the graphic expression of the drawing and the architecture of the building. However, to achieve this, not only a good CAD system is required but also graphic thinking by the architect.

Of course, it is a big step to change one's way of working *from* presenting buildings in plan, section and facade *to* building an altogether logical 3D model, from which are taken the projections needed for various purposes. This is a very important research and education task for the institutes of technology before the practician can change his way of working. It is vital that the schools convey in their CAD education more than an insight into today's commercial CAD systems. They must give the students knowledge about what the systems may look like in future.

At *the University of Colorado* they have taken the concept of "Information Management" seriously. They are looking for a connection between the CAD system used by the practician and the information required for planning, for example on different performances, building materials and regulations. They use the technique which is today called hypermedia but which has its roots far back in time. Vannevar Bush published his thoughts on this concept in 1945 in the article "As We May Think". In short, the aim of the hypermedia technique is to search associatively in a database, jump between different "nodes" to find the

desired information. The "nodes" are not only intersections in a mass of text. They can also unite the CAD system with the texts - a HyperCad system.

The architectural schools in the USA, among others the *University of California* and the *University of Michigan*, have for long used computer techniques to develop the architects' knowledge of climate and energy. By means of the new technique, that which is not seen is visualized, for example the distribution of sound-waves in a concert hall not yet built. Another example is clear consequence descriptions of how the temperature varies - and what energy increases are required - depending on how the architect places and designs the building. It is thus a matter of systems which analyze, calculate, simulate and visualize. When the students meet these systems, they realize how sensitive the design of the building is to the indoor climate and the energy consumption. However, the systems also guide the students how to best perform their task.

In a computer animated film from the *University of Houston* it was shown how a whole group of students cooperated to present Houston and its campus in a computer animation made by AutoDesk's Animator. It was thus a very simple animation. The film was convincing, simplicity in combination with a fantastic abundance of ideas showed exactly the creativity we want to have in the architectural schools.

The overall impression is that many new ideas are sprouting out of these experimental activities. The direction is clear. A large number of application programmes for individual design tasks are on their way to the practicians. Some of them are already commercialized and available. The development of which I have here given a few examples does not refer only to new computer systems or individual programmes. It also implies

that the design process is examined and demystified. In an international perspective, we have in Sweden advanced very far when it comes to development and application of computers for the planning and design of documents. What could be further desired is that we make use of the foreign knowledge of how to improve design work by means of computer aids of various kinds.

Are houses and environments getting better?

The introduction of computers has led to an increased interest in the research called design theory. It gives us the concepts to talk about design work and formulate theories around this. It is an indication that researchers and practicians are anxious to keep alive the old knowledge of how to create good architecture and how to present it in sketches and drawings. It is not possible to build good computer programmes *for* design if the knowledge *of* design is limited to the pen. This research, as well as much of the development carried out in the American architectural schools, shows various ways of looking at the relationship between designer and computer. It has contributed to a deeper understanding of the designer's soft way of working and that conflicts between designer and computer are in the first place due to shortcomings in the computer technology.

But will architecture get better? Yes, the "multiplication architecture" which many fear will be the consequence of using computers was applied before starting to use computers in the construction industry. The planning ideals behind "production functionalism" are out-of-date and do not work on today's construction market. These ideals are not included in the design tools which are now developed. Furthermore, the more

complex a building is, the more interesting it is to process its geometry in a computer. I do not think the *computers* limit our possibilities of creating better architecture. On the contrary, we are enriched by new means of expression, as for example rendering, real time animation and multimedia and the ideas can thereby be better *visualized*. Whether this will make the houses look different or not, is difficult to say. Maybe more progress is made in other areas. The American examples showed great interest also in other aspects than the exterior of the buildings. Framing facts in architecture are, among others, climate, energy and acoustics. Several experiments were aimed at producing aids for the designer to treat these aspects in a better way than has been possible so far.

When we are able to *model* a building as a whole, we can also for the first time *simulate* for example the air flow in the building and determine its quality. We can *estimate* life-cycle costs and the economic result of real estate management already when the choice is made between different technical solutions in the planning phase. These are examples of how the building's performance may in advance be improved and determined in more detail.

4 FROM CAD TO IT - CHANGEOVER OF WORKING METHOD

CAD systems - a good investment?

In the shadow of the financial crisis which is now devastating parts of the Swedish construction and consulting companies, there is every reason to examine critically how the companies acquire fresh know-how and new techniques to develop their working methods.

Sooner or later the companies must, among other things, evaluate the results of the investments of recent years in computer aids of various kinds and what future developments are needed. Have these investments resulted in the increased capacity and quality improvement promised? Today, companies in the construction sector as well as in other fields have reason to ask themselves if their computer strategies have been right. For some, the question is even if the computers should be put aside and manual working methods be reintroduced. However, it is at the same time stated that the change-over from a manual way of working to computer aided methods is a fact, and new architects and engineers use the new tools.

These questions may seem to be internal matters for the respective company, but, in actual fact, the introduction of information technology in construction has raised several questions of common interest to this sector. This is, among other things, illustrated by the joint concentration

by the Swedish Council for Building Research (BFR), the Swedish National Board for Industrial and Technical Development (NUTEK) and the Development Fund of the Swedish Construction Industry (SBUF) on a national programme for information technology which has been running for almost a year at special centres at the three institutes of technology in Stockholm, Gothenburg and Lund. A central concept in this concentration is so called product modelling. This has come to engage researchers as well as planners, building contractors and real estate managers.

Let me illustrate briefly some of the questions that may be raised on the possibilities of effecting the change in working methods constituted by information technology and say something about the strength of the winds of change involved in the new infrastructure for information processing. I will limit myself here to look at these changes from the perspective of the architectural and technical consulting companies.

Computer aided drawing

During the last decade, the CAD technique in the form of computer aided drawing has been introduced. Today, as much as 80 per cent of the Swedish architectural and technical consulting companies use systems for computer aided drawing. After a very hesitant beginning, the bulk of these investments were made during the last years of the recent business boom.

The reason why rather simple, but well-functioning 2D CAD systems with visualization possibilities run on powerful personal computers are successfully used in the offices of many architects and technical consultants is that they are regarded as tools among other tools. The CAD system is seen as an electronic pen well adapted in a tested tool-box. With

these systems, drawings are reproduced, not the three-dimensional building with its technical specification.

The introduction of computer aided drawing has been made maintaining the traditional role-casting in the architectural and technical consulting companies as well as in the building process as a whole. Exactly the same reports and documents as those produced before. The results are printed out on drawing film and the copying agencies' messengers deliver copies to the clients. The division of responsibility between different actors is only marginally influenced. The sensitive sketch process is affected very little.

The increase in efficiency so far achieved by computer aided methods has only applied to certain sectors of the construction process and has by and large only paid for the computer introduction. The information is not being forwarded to be reapplied or used for other duties, for example calculations. Certain positive consequences may be seen in the form of more meticulous, and in certain cases better coordinated, documents. The greatest importance of today's technology lies in its having paved the way for a future modernization of the construction process.

CAD is leaving the beginners' stage - product modelling

The computer aids of the future (CAD systems) will not have the drawing as its object and model of representation. It will be an information system built on an ingenious and multi-purpose representation of the building. The idea is that the information built up by, among others, the architect in the early stage of the construction process will be reused time and time again during the construction for production planning and follow-up

purposes, and its objectives are to be of use during the long administration phase.

The graphical and alpha-numerical representations are interconnected in an object-oriented relational database. From the database, the documents needed on various occasions are projected, for example drawings, descriptions, calculations, quantity specifications. A change of a detail in the database results in a change in the graphical representation. The same detail occurs only once in the model. This presupposes, however, already defined, distinct connections between data, i.e. a product model.

In this way, it is possible to analyze, simulate and visualize. To make a load analysis directly from the product model, to simulate air flows in the building as a whole, to visualize the light processing in a room, schematically or very lifelike, where for example the materials handling can be shown lifelike in a mixture of daylight and artificial light. You wander through the model in real time - i.e. the computer counts so fast that the pictures are produced in a film sequence, whose contents are decided the very same moment by the person who looks at the screen. Another application for this technique is to plan and visualize the work on the building site in advance. For the benefit of production planning and organization of the work with regard to the safety of the building workers.

Great expectations are also attached to the possibilities of making an automatic quantity take-off for cost calculations in the various planning stages.

The intended working method means that the computer systems are interconnected with one another in the offices and between the offices.

They connect architects and designers with one another - today we talk about groupware, interactive, decision back-up systems.

From drawing-oriented to model-oriented CAD

On different levels work is in progress on the preparation of a changeover from drawing-oriented to model-oriented computer aids, and a gradual change of CAD technology is taking place. From today's system based on the computer being used as a drawing tool in a "traditionally" organized planning and design process, to a future system where the building to be is stored in a multi-purpose manner in the computer through so-called product modelling.

It may be mentioned incidentally that at Chalmers we work with an application within the IT project mentioned earlier which we call "Computer aided Building Box", the aim of which is to enable good solutions to be saved, retrieved and reused in a rational way.

The product model is a (future) standardized agreement regarding the kind of structures in which the information about a building is to be arranged. Such prestandardization is going on in the USA and in Europe. The halting Swedish steps in this matter require a separate report.

My point here is that product modelling contains another dimension than computer aided drawing. The manual working method cannot be copied. *We will not make drawings of houses with computers but model the prospective building*. A new approach will be introduced. The company's work methodology in the planning and design process as well as its products in the form of documents will be changed. The same is true of the forms of the company's responsibility and its debit system. The new technology will thus affect the architectural and technical consulting

companies as a whole, but also the companies' relation to the world around them: clients, sub-consultants, building contractors etc.

Maybe, it will therefore be impossible to introduce this technology into the construction sector in spite of the fact that it fits into other fields?

For the architectural and technical consulting companies that want a strong position in the building market of the 90s, it is necessary at least to consider the possibilities of the new technology. To describe its consequences and business opportunities. To examine critically whether the obvious possibilities of the technology can be combined with what the customers will request and are willing to pay for.

What, then, argues in favour of this picture of the future having some degree of credibility?

User's demand for the computer systems of the future

New forms of procurement - new demands for documentation

One background factor of this project is the new demands for the work of the architect and designer by the world around them. It is no longer self-evident what documents a firm of architects should produce in a project. New forms of procurement, procurement through negotiations, split contracts and design/build contracts mean that the information in the consultants' documents is to be stratified in a new way and be completed at other points in time in the construction process than before.

This requires planning and design systems which permit quick and reliable editing of information.

New role-casting between the building material industry and the planners

A new distribution of tasks between, for example, the architect and the producer of building material means that, in certain respects, the architect will draw fewer details and, in other respects, will have greater possibilities of working out standard components in detail. The building material industry wants to sell complete sub-solutions including design but will also, through its computerization, offer the architect the opportunity of working out in detail what were earlier fixed designs. The products of the material industry are illustrated in digital catalogues which are available direct via the planners's CAD computer.

If the architectural company wants to play a leading part for the product determination in future too, it will probably be necessary to communicate with the material producer and interactively describe and evaluate various designs. This will be done via CAD models.

Electronic trading

Automatic quantity take off and computer aided cost calculation make the contractor's work more effective. However, what is known as electronic trading will above all change the traditional work pattern. Invitations for tenders will be drawn up according to international standard, EDI, and purchase and delivery agreements will be made via computer networks. This can be facilitated if there is a digital model, a product model, structured in a way agreed on in advance for the sector, from which quantities and specifications can be obtained. It must, of course, be possible to do this at different stages of the process and with various degrees of exactitude.

Catalogues, experience, regulations in open databases

The building industry's rules, in laws, directives and standards, are now beginning to be available via databases. This means that they can be updated more quickly than today.

The products of the construction industry are now being made available for documentation in CAD systems. This also includes information on building supplies in the Swedish Building Center's big database, which is now being modernized, and the vast amounts of information in libraries and experience banks such as Byggdok (documentation compiled by the Swedish Institute for Building Documentation). Lists of, for example, hazardous materials or approved designs will probably be of great importance with a view to finding good solutions and protecting companies against large claims for damages. Searches can then be made direct from the architect's office.

With the help of so called knowledge systems, an intelligent search is facilitated in these databases. It will gradually be necessary for the architectural and technical consulting companies to have a direct link with these databases.

Geographical information systems

Geographical information systems are now being developed at local authorities. In the long run, they will contain basic data maps (terrain models), current detail plans and information on the technical infrastructure: road networks, supply systems etc.

An increasing number of data, also demographic and social, are being given coordinates.

The architectural and technical consulting companies have a direct need for access to this information. Information on completed projects must, however, also be given to the databases of the local authorities.

Comupter-aided real estate management

The design, construction and management process may be seen as an information process. The information built up in different stages of the process can be handled financially and be reapplied in the management phase. In my opinion, the design phase should not only result in an enquiry documentation but also provide basic data for drawing up a multi-purpose management document.

In my vision of the future, the outlook on the management of buildings is widened from a purely technical perspective to a strategic one where the information on the possibilities of the building comes to the fore. Therefore, the management document should comprise data for care, running and maintenance as well as information on the building's structure, technical systems, fixtures and flexibility of use. The information should be accessible and presented in such a way that the present and planned use of the building is easy to understand. The structure of the information should be in agreement with the substance of practical and strategic management work.

The demand for the substance and design of a management document will, therefore, differ strikingly from the traditional building document, which is today accorded a central position in the construction sector's contract and responsibility system.

Today, the idea of a particular management document is often restricted to a somewhat enlarged relational drawing. Strategic

management, however, presupposes information which gives an overview of the real estate property. This applies to its location, size, contents and design, technical condition and use as well as its financial position: investments, loans, rents and income etc. One basic demand is that the information is comprehensive at a predetermined level and that it is up-to-date and correct.

What is needed in practical management is a combination of schematic, general information on each single property and detailed, technically precise information on certain components and technical systems in the building. It may, for instance, be a question of general information on letting and necessary reparations, detailed information on locking systems, care of the ventilation equipment and emergency measures in the event of leakages.

In the event of alterations, much of the information available in the original building document is, naturally, needed, but it must be adjusted "as built". It is then a matter of coordinated and highly detailed information.

Every major real estate manager has large archives of drawings with data about existing properties. This information is very rarely suited for immediate use neither in strategic management, nor in decentralized, practical management. The real estate managers will in future have to pay particular attention to the question of how old, extensive drawing archives may be used.

Some of today's management is computer aided, for example letting. The question is how the administrative data processing can be combined with information based on maps and drawings for the presentation of strategic data suggested above.

It may become an important competitive device for the planners and designers to be able to provide a product model which meets the requirements of real estate management.

Consequence description through simulation

One result of the new system of responsibility which is now being discussed with a view to its introduction into the construction sector may be fewer governmental building regulations and more court decisions. As a result, it will be important for the companies to document what conditions and quality levels are to be reached in the individual project in order to demonstrate that the company has fulfilled its commitments. Among other things, it is a question of assessing whether the prescribed functional requirements have been met.

As I mentioned in the beginning, so-called product modelling means in principle that a complete model of the future building is stored in the computer. On the basis of this, it is possible, for example, to simulate the outcome of different designs and to carry out advanced, photo-realistic visualization with the aim of making it possible to understand and assess what has not yet been built.

Computer aided quality assurance

Concurrently with the late computerization in the building sector, efforts have also been made to introduce systems for quality assurance. New forms of procurement and increased competition have resulted in the fact that architectural and technical consulting companies have been looking for methods to enhance the efficiency and lately also - as a consequence of the deep financial crisis - the productivity of their work.

However, there are probably few companies which have managed to utilize the full potential of their computer systems, as the computerization has taken place within the framework of the traditional manual design process. The digitally stored model of the future building has, as mentioned above, remained within the office. The joint rules needed to bring the model to the attention of other participants in the construction process have been lacking. As a result, the possible increase of efficiency has failed in part to materialize.

It has also turned out to be risky to incorporate standardized quality assurance systems in artistic work, and many people question the possibility of producing good architecture when faced with demands for increased productivity. This "overall" uncertainty is, in my opinion, based on the fact that, to a large extent, people are unaware of how their work is in fact organized. It has so far been possible to work wholly traditionally in a drawing office, studio or one's own "den". However, in future this will not be enough. The companies will have to become more professionally organized. Computer aid in various forms will, in my opinion, be required to increase productivity, at the same time as the quality of the products of the companies may be assured in an economical way.

New forms of expression

At present, there is no computer system suitable for sketching the way we look at this concept today. However, it is not possible, as we have done so far, to computerize the work but avoid the sketch phase. The traditional division of stages is changing, and wishes for, for example, early cost

calculations with great accuracy will neccessitate sketch modelling of different alternatives.

This means that we have every reason for trying to describe how the new technology influences the core of the architect's work. Probably, there is a strong relation between the tools we use in the very special work of design and the result of this work. It is easy to raise many critical questions as to how the artistic work as part of the building process will be affected. At the same time, many artists and architects see opportunities for new expressions through the medium of computer techniqes.

Internationalization

Our way of drawing and describing houses must be open to the demands made on us from an open, international market. Already today, architectural and technical consulting companies cooperate with colleagues abroad. Our respective computer systems must be synchronized. The international standardization work for product modelling is under way at present, and a specific part of this work concerns standardization of product modelling in the construction sector in Europe. Knowledge about this work among practicians is low in Sweden, and insight into this standardization work and its results may be a competitive device.

Change of working methods

Together, these development trends may be a strong force of change which already now affects the values we have of the methods we use in design, construction and management.

As a result of this force of change we will see a changed design and construction process with a new division of stages and roles between different occupational groups. We will need to describe the new patterns of cooperation appearing right now. Many descriptions of the construction and design process are far too simple today, with its linear courses and schematic, trade-guild stage divisions. This hints at the fact that concept development for the design and construction process is an urgent field of research. It is an urgent research task just to be able to describe the new patterns in step with their formation. The result of such research will help the practician to see clearly.

The introduction of IT means a change in work methods of a totally different dimension than before. It is the matter of a change of technology with positive and negative consequences. The introduction of IT will not be successful if we do not form an expoundable conception of what characterizes the creative and construction process (the design process). We must understand why the work is carried out in a certain way. The computerization must be based on a deep knowledge of the professional contents.

We will see the growth of a number of professionally run companies. Few have seen the architectural firm as the mould in which the creative architectural work is organized. A superimposing of free creative and personal exploratory work and the systematic, well organized project group work. The introduction of computer systems, quality assurance systems as well as methods for increased productivity have indicated the need for a renewal of design methodology. The actual change of technology will put the company managements to the test and require its own strategy.

In order to be competitive in the future, it will be important to be able to reapply and perfect good, reused solutions, to have access to reference solutions. It will be important for the companies to know how to use general know-how and to be able to put knowledge formulated by others into practice. This requires a systematic way of working and knowledge of how to utilize the database approach - in the individual project, in the company's own experience banks and in general, joint databases.

Major investments in equipment will be necessary, but above all in the form of access to competence. This will contribute to strengthening the change of company structure triggered off by the financial crisis.

5 AN INFORMATION TECHNOLOGICAL INFRASTRUCTURE

Strategies

The construction crisis has made construction and technical consulting companies reduce their costs in all conceivable ways, by dismissals, discontinued development work and cancellations of tenancy agreements. What financial possibilities does the construction industry have to invest in information technology?

After the costs of personnel and premises, the computer cost is the largest element of expenditure in the budget of a technical consulting company. As many of the companies have not analyzed the revenue aspect of computer investments, IT is only seen as a cost. Its importance as refers to increased productivity and quality is underestimated. To a large extent, computer investments were made in the last, over-heated phase of the boom. Their motives were often carelessly formulated - it was only a matter of "keeping up with" development.

The purchase of computers was initiated by young staff from below in the organization. This is in itself a good sign of growing awareness with the coming generation of actors, project managers, group and office managers. However, company managements have not paid enough attention to the fact that a special computer strategy and a management programme are required for IT applications in the companies. The ultimate responsibility for a company's administrative and technical

computerization must be taken by a person selected for this particular purpose. This person should be part of the company's management. There must be an organization for how to branch off the responsibility within the company and to the individual projects. To draw, build and manage houses means having a responsibility for very large amounts of information. Accuracy and discipline are required by the user so that everything is correctly systematized from the beginning. This is a condition for making good use of information technology.

Of course, computer strategy is obviously an issue for the board of directors. The investments are large and the depreciation period is short. The long-term direction must be agreed upon. Information technology directly and indirectly influences the company's business internally and its external relations - with clients and with other companies using IT. There is a strong connection between the company's products and its organization, know-how profile and information technology. Therefore, the computer policy is an issue for the company's management.

In the 1980s, many companies were bought up and merged. The development has been similar for both construction and technical consulting companies. Very big technical consulting groups have grown up. Small and medium-sized companies with a varying degree of computerization have been mixed into large company groups. It has been important to keep the companies' local network of contacts with clients and their own way of working as building projects are often local. The branch offices have been able to deliver profits during the over-heated years. Therefore, the policy has been to "let the boys run the systems they like and are used to". This has also been a comfortable attitude.

Managements have not had to learn all the new things in information technology.

Now the crisis has come and a clearing of the computer mess is needed. What types of computers have we got and how many of them have been upgraded to acceptable performance? What licenses and agreements of updating have we signed? For how long are we bound by various agreements? What is being leased and what are the depreciation periods of that which we have bought? Why do we have so much software which is closely related and even several different CAD systems in our company? Why do the different divisions have so many different methods of planning? Why are CAD projects stored and filed in different ways? Is the storing of the drawing files consequent? Do we dare to supply the clients with the drawing databases as they have now - suddenly - started to require?

By personnel reductions the companies have involuntarily become more and more computerized, as was said in chapter 4. The law on protection of employment has led to the fact that young, computer literate employees have had to leave the companies first. There the computers have been left idle with unused computation capacity. The second hand market for two to three year old computers is not bright, even if it exists on the other side of the Baltic.

What will happen now?

On the one hand, the conservative professionals emerge on the arena. The CAD explosion was only a paranthesis; now we must go back to professional know-how and well proven ways of working, is an opinion which was for example expressed by a well-known Swedish architect at the annual congress of the National Association of Swedish Architects in

1992. Many, somewhat older professionals, who have never bothered to learn the new tech-niques, and who are thereby partly responsible for the careless introduction of them, now hope to escape the development again. They simply suggest that the computers be put aside and they go back to what is old and secure - to be a "real" architect again.

On the other hand, the clients have now had time to get used to the advantages which the CAD technique no doubt gives them. Real estate proprietors, clients and managers have started to ask for copies of drawing files because they need them in their digital drawing archives. And when it comes to it, those responsible for the CAD technique admit that it has come to stay. In many offices there is in practice no doubt about the fact that the jobs should be planned by CAD. The computers are sent around to the divisions involved. They try to make maximal use of their computer capacity instead of acquiring more work stations. Project administrators and managers must be trained in CAD. As a good example it can be mentioned that a big Swedish architectural company is running a project called SeniorCAD. This is very promising as it is now, but only now, that the really skilled architects and engineers are becoming CAD users. They have a long experience and understand how to correctly combine their professional know-how with an efficient aid.

I know of chief engineers who have said, after having in just a few days learnt the basics of CAD, that "this is the aid I have been longing for all my professional life". They make up the professional category which is responsible for the correctness of all details in the extensive building document in every respect. They administer all changes in the documents which come up day by day, from the start of a project to a finished building, and they must assume the responsibility for errors detected in

the documents. Now the tool is available to make this extensive information handling more efficient.

Bill Mitchell at Harvard, Boston, has expressed it this way: Exactly as we have seen in the 1980s that word processing has been accepted all over the world, we will in the 1990s see how architects find it natural to use CAD systems to make various representations of buildings. This will be the most common way of planning. We will not experience it as a revolution. However, the way of drawing which is so closely associated with form and design will be developed.

As I can see it, the construction industry is implacably entering the information society and it must use the possibilities of information technology to be competitive. Who believes that the aviation, car or electronics industries would at all think of questioning *if* they are to use IT for design, production and technical documentation? No, international industry exposed to competition concentrates hard on the use of the best IT aids. Its interest in, and use of, for example model oriented CAD systems, I see as a model for the construction industry, in spite of the many differences between the trades.

One objection is that the construction sector consists of so many different companies that they form different constellations for each individual project and that these are dissolved when the building is finished. Engineering companies can more easily keep their sub-suppliers together and it is thereby easier for them to make use of the advantages of IT. But is it not so, on the contrary, that exactly due to this fact the companies in the construction sector ought to build IT networks and communicate more effectively? There is a great potential in these very

communication possibilities and a chance of creating an integrated construction process.

Economy and lack of resources for new investments in IT accentuate the need for making priorities and see to it that each single measure is part of a context. My conclusion is that IT strategies are needed in the construction and technical consulting companies. Common rules of the game are needed for the communication between companies in the construction sector, i.e. strategies for the construction sector's IT application.

Standardization is one feature of such a strategy. Administrative directions of the type provided by the Swedish Building Centre is another one. Research and development is of basic importance for that which is specific of the construction sector's use of IT. BFR, SBUF and NUTEK make substantial contributions, even if they ought to be much larger. Training in construction IT is also a strategic area of common interest. Lack of competence is one obstacle to overcoming the technology shift. Even if it is difficult to make comparisons, it has been asserted that the proportion of graduate engineers in the engineering industry compared to the construction industry is seven to one. This is probably one of the explanations of the difference in computer knowledge. However, the educational institutes in the construction sector persistantly continue their short courses in CAD and have not yet understood what IT is.

Several fora of discussion on what questions are of common interest have already been established through our trade organizations.

Who takes the initiative in creating an IT strategy for the construction sector?

Standardization

Standardization is a well proven form of rationalization and quality assurance. It is a border-crossing, international movement which contributes to industrial development. In standardization committees, the principal representatives of product development from all countries meet. The standards are the result of negotiations in these committees.

So far, we have in Sweden been used to building standards mainly dealing with industry products. However, the administrative processes may also benefit from standardization. The messages and information flows of the construction process may be rationalized. Swedish and international standards for documentation in drawings are good examples of successful work of this kind. De facto standards like Administrativa Föreskrifter (administrative directions), AMA and the BSAB system (the Swedish development of the Sfb system) are other good examples.

One experience of work of this kind is that it is the matter of making agreements between many different parties and that such work takes a long time. From a logical point of view, BSAB is not a perfectly built-up system but more of a very good negotiation product, and it works because it is accepted by many. The classification work needed for revisions of this kind of systems should be going on continuously to guarantee application possibilities and keep negotiation results up-to-date.

The international development leads to agreements on how information on buildings should be structured to make it possible to handle it efficiently in computers through the planning and design, construction and management process, without intermediaries in the form of manual handling. Several efforts with this aim are being made around the world. One of the most important efforts for the European market is

the so called STEP work on digital transfer of product information. Of course, there are many ideas of what should be the nature of the so called product model, but already the endeavour to achieve such an important standard results in significant development. A proposal for a standard of product modelling already exists for the shipbuilding industry.

In order to make clients aware of the fact that the digital information which architects and designers produce is really reusable in long-term real estate management, a national, Swedish agreement on NICK, neutral intelligent CAD communication, is at present under way. This work is well in line with the more extensive STEP work, but the time frame is luckily much shorter. The prototype has already been successfully tested. The clients may already now contribute to urgeing the development by making agreements that the project databases should be supplied in NICK format.

The materials industry has taken the initiative to a prestandard of describing building components, housing and installation parts, in different CAD systems. They can thereby provide descriptions of all their products on disk so that the planners can use them directly and without detours in their CAD systems.

Another strategic piece of work is EDI, the electronic data interchange project, which is carried out in a specific EDI association with the Swedish Building Centre as the cohesive power. This refers to standardized forms of materials messages, for example between building contractor and supplier. Electronic trading is of course a new, important form of business deals with its scope far outside construction industry.

The forms of digital information flow in and between companies are on the whole of great importance, and it is obvious that this means a tremendous market for new services and products.

In the computer industry, the development is now fortunately heading towards a standardization of operating systems, interface (i.e. how the user communicates with the computer), graphics, database language and communication between different computer systems.

Components of computer systems will also be interchangeable in a totally different way than before. The ready-made, closed systems become less and less interesting and so called open platforms have come into focus. These are of great advantage to the users, as is also the substantial price cuts of computer power.

The driving forces behind different standards for IT in the construction sector vary. For companies being in an intital phase of computerization, the interest in standards is low as long as IT is used for limited tasks in certain stages of work. Maybe they are looking at market leading companies in the same trade to make their own choice of technology easier. However, as soon as they want to bring about an integration of various tasks and exchange information between companies, their interest grows strongly. Certain big companies try to bring about a vertical integration of computer aids of different kinds within their own company. In this way, the strong companies may try to set a standard for the whole trade. However, it is very costly always to be a step ahead and indirectly pay for the computer competence of the other companies. As a kind of counter force, the interest increases to make, step by step, common agreements for the whole construction sector, which may in their turn be harmonized with the international ones.

Databases

Database technology is one of the areas of IT which may give the fastest rationalization gains. It may be applied to at least three different levels in the form of project databases, companies' own databases and common, public databases.

Project databases

By means of project databases, all the documents included in the project may be structured. In manual planning, the project database is the total pile of drawings, descriptions and calculations. By means of computer aid, the *document handling* may be rationalized. The concept is central in this context. Through database technology, the individual documents can be related to each other and coordinated among themselves. This facilitates revisions and makes it possible to keep various versions of a document in order. A simple form of project database is the drawing pool in which all the participants store their drawings digitally. It makes it easier to be up-to-date and to coordinate work. In the more advanced, model oriented systems it is not a matter of drawings but of all these data which are entered into the product model from which documents may in their turn be projected for various purposes.

The companies' own databases

The total construction know-how represented by a company may be made accessible to all employees and be used for new projects. The company database is one way of making use of and reusing know-how built up in each project which may otherwise be lost after the project is finished and the project group is scattered.

In the product decision phase, the planners may get hold of reference solutions from the company's own database. They can see how the company has solved similar problems before and retrieve relevant documentation. Thanks to new storage media such as CD-ROM disks and good search systems, this information may be made very easily available. Drawings, descriptions, specifications and photos are presented.

The company may step by step build up libraries with good solutions which are refined through the experience from several projects. The know-how of the managers may be brought back to the planners.

Public databases

At present, one database after the other is being accessible to the construction sector; the Swedish Building and Planning Act, the building regulations of the Swedish National Board of Housing and Physical Planning, the Swedish Building Centre's database with 47,000 building and installation products, Byggdok's (the Swedish Institute for Building Documentation) R&D archives, etc.

In the tremendous growth of information, not least research information, a well-balanced use of computer technology is a condition for being able to search, retrieve and use relevant data from public information banks. A stronger concentration than before on the application of the new aids may contribute to better buildings. Thanks to databases information has been more easily available than before and it may be kept up-to-date in a more rational way.

The problems of sick buildings have proved that the construction process must be supplied with, and be able to make use of, more facts about people's sensitivity to various building materials and their

characteristics. It is not enough to roughly say or guess what is, for example, the best balance between sufficient air change rate and tight, energy conserving constructions, what material combinations are healthy or what solutions create a good environment for the construction workers.

Intelligent use of computers in the construction sector may come to play an important role in communicating knowledge about the problems in the construction sector and possible solutions. The knowledge is there already but is not being used as it has not been accessible in a comfortable manner. However, much still remains before the databases are connected, given a similar structure and have search systems with user friendly interfaces. Research on IT in the construction sector may further contribute to making information in databases easily accessible.

In a first step, codes and R&D results have had the form of digital reference books. However, the point of database technology is that data from the information sources can be linked and relate different pieces of information to each other. Someone searching for a concept should be made aware of what is said about this in the wording of an Act as well as in regulations, standards and collections of examples. Those who run the databases and sell information retrieval must understand that this is the cross connection that the user wants. With such a connection, the public databases will be frequently used and worth their price.

Electronic tool box

A considerable share of a consultant's work consists of developing technical solutions to various problems. A proposed technical solution is an expression of a compromise between, among other things, desired shape and function, economy and construction practicability. This

"technical development" takes place within the frame of planning and design of systems and building documents in concrete projects. In spite of the fact that the technical solutions are the same in many projects, the descriptions of them are compiled as if they were unique. Thus, many designers work on documentating the same solutions in the form of drawings and descriptions again and again. In a firm of architects, for example, also complex technical and aesthetical solutions are often repeated in several projects. It is not unusual that successful architects have a "tool box" with well proven, good solutions. In spite of this, no method has been developed to make use of and easily retrieve these solutions.

The drawing archives of the firm of architects are organized by projects. Today, old drawings are retrieved and copied. The CAD technology has opened up new opportunities for making use of and further developing these solutions. However, today's CAD systems are oriented towards drawings. Their paragon is the firm of architects as a producer of drawings. The CAD system reproduces drawings - not intelligent and variable models of prospective buildings. In today's CAD systems, information is stored in rigid structures.

As mentioned earlier, in future model oriented CAD and information systems, graphic and alpha-numerical representations will be connected in a relational database. The file structure is then open and different partial solutions for different building components can be stored in directories.

One of the IT building projects at Chalmers University of Technology is called interproject databases. A method has been developed to structure the description of various partial solutions and organize them in a comprehensive directory. In addition, a concrete application is

developed of a component directory in an object oriented relational database. Particular attention is paid to the interface, i.e. how the designer can search, retrieve and make use of stored solutions.

What companies can do in a short-term perspective

I have presented a few concepts with the aim of organizing the thoughts in order concerning the technology change in the construction industry as a result of the introduction of IT.

I have given a picture of the future planning, construction and management process as a communication between different actors in networks. The quick, interactive decision making in the network is made possible by using various forms of data communication.

I have tried to make it credible that the core around which this communication circulates consists of a product model, successively more and more elaborate, a representation in the computer of the prospective building. From this model, the actors can collect the facts which they need about the object in question for the project concerned.

I have tried to illustrate the fruitful idea of using different kinds of databases to make use of past experience, include more facts in impact descriptions and strongly increase the companies' productivity.

I have pointed out that the development in itself and the introduction of IT in the construction sector can be handled in a much more rational way if research and standardization are brought into focus.

Even if I share the feeling that the construction sector is changing very rapidly right now, as a consequence of the building crisis, it is my opinion that this technology change will take a long time. We will be working in a transition period between manual and computer aided

planning and design, building production and management which will extend another couple of decades into the future.

In the short-term perspective, we will see many different applications of parts of the IT concept, loosely connected in fragile networks and resulting in the joy of discovery as well as much trouble for those responsible for IT in the companies. By means of well defined IT strategies, development could, however, be guided in the right direction in small steps. The companies could then both benefit from short-term efficiency gains from using computers and also resolutely enter the information society. The most important thing is to have a *strategy*. In addition, the right *techniques* to make work more efficient must be used.

These are a few examples of small steps which will lead to an extended application of information technology in, for example, technical consulting companies:

Platforms

* Increase the utilization degree of existing techniques.
* Increase the computation capacity by upgrading computers, operating systems and programmes.
* Improve the configuration of individual work situations. Ensure that the parts of the systems as a whole work better together.
* Utilize new storage media, e.g. optical disks, which make filing more efficient and increase safety.

Communication

* Install local networks for project groups with joint archives.

* Use data communication for transmission between companies in different places.
* Use e-mail, data record.

Programmes

* Utilize links between different kinds of software. Reuse information logged into an application programme as a basis for work in the next one - i.e. see the connection in the chain of drawing, description, estimation, visualization, simulation, quantification, calculation, production control, etc. One example: If correctly formulated, the designer's reinforcement specifications may be used for automatic cutting and bending of reinforcement bars.
* Widen the computer support and make use of the advantages of, for example, scanning and computer aided scaling and measuring of landscape, buildings and plants.

Planning and design management

* Introduce computer aid for design and project management, for administration of projects.
* By utilizing the flexibility of the storage structure in the CAD system, information may be reformulated and used for management.
* Improve planning and design methods and document them in manuals for computer aided planning and design.
* Adapt menus, symbol registers, storage distribution etc. to the conditions of the company or project.

Standards

* Use trade standards pending official international standards, for storage distribution and filing of projects and as a framework for internal adjustments.
* Use the NICK format for transmission between different programmes.

Databases

* Structure each project so that its parts are reusable and easy to retrieve.
* Introduce routines for filing.
* Negotiate the resuse of drawing databases in the construction and management phase.
* Use common databases like Varudatabasen (component database), PBL, Byggreglerna (building rules) etc. instead of printed media.

Information technology is described by a large number of new words. Unfortunately, this is probably obvious also in this text. The fact that a computer is easy to use, for example, is expressed as "a user-oriented interface". There exists a special reference book for data freaks with incredible examples of this peculiar technical language. The computer technology's annoying, *little* shortcomings with its attached technical jargon are among the major weaknesses of information technology.

An IT slum also exists. Offices are filled with awkwardly placed, ugly and noisy computers. Semi-drawn curtains and weak lighting do not create a nice work environment. Randomly chosen desks, chairs, lighting fittings and colours are bad for human work at computer screens, which also frighten people due to the much discussed magnetic fields.

Apparatuses placed directly on the floor, enormous tangles of cables and static electricity do not facilitate tidying and cleaning.

It must become easier to use computers, programmes and networks. The techniques must stabilize, the programmes must be clear and the networks easy to administer. To actively reduce all the refinements of information technology and instead concentrate on the easy use of the most frequent applications is maybe the best way of urgeing development. Otherwise we are running the risk of a "hang up" in modernizing the Swedish construction sector.

Can Swedish architecture and construction cope with IT?

The building crisis is deep and construction companies request government contributions in the form of an extension of Sweden's infrastructure for communications and continued subsidies to ROT (repair, alteration and extension) programmes and new production of housing. It would be alarming if subsidies were the only way of getting the Swedish construction sector started again. Calls for more subsidy politics aside, in which other ways do the companies and their different professional groups show that they are offensive and can find ways out of the crisis by themselves?

The companies cut their costs and have in certain cases achieved a considerable increase in productivity. However, as a whole the impression is that the Swedish construction sector is being dismantled. There are many examples where research and development have first had to give in, in spite of the fact that in the long run this is the only way of developing companies and being competitive.

It is being discussed if we should instead construct technically more uncomplicated buildings. Newly produced buildings, with extensive technical installations, are expensive to own and manage. There have to be savings in all phases: simpler planning and design, building production and management. The work process as well as the products, buildings, should be simpler. The thin building documents and simple, cosy houses of the 1950s are emphasized as worthy of imitation. It seems all very handy.

What other modern branch of industry would meet the future by winding up its research and product development and offer the customers a model from 1950? I refuse to believe that the construction industry's managers would accept that their trade is considered second raters in industry, that they would not be able to produce modern products at the right price.

To a large extent, product specification, production as well as management is a matter of combining in projects different competences and transmit information between a large number of people. The systems and building documents of designers, the material management messages of contractors and the real estate registers of managers are all extremely dense with information. Information technology offers an infrastructure for this information handling straight across the process. Why is the construction sector not more keen on quickly making use of tools to make this piece of work more efficient? How can we make the construction sector learn how to use the tools which our children use?

The computer industry will not help the construction sector enter the information society by giving subsidies to necessary investments in hardware. Nor is it likely to develop ready-made systems. Previous

attempts by the computer industry to, as it was actually called in certain places, "redeem" the construction industry have failed. Its role will probably be to supply open platforms and sell advice, in keen competition.

Nor will the Swedish state subsidize the construction industry's modernization. On the other hand, government R&D efforts contribute to the extension of the information technological infrastructure.

The building industry's companies can thus not wait for someone else to come with complete solutions to building computerization. Trade organizations, or individual companies, must themselves formulate demands for desired features in the systems. This is a problem as designers, constructors and managers boast of being people of practice. It is difficult to create an interest in theoretical specifications of requirements. Designers and constructors are often rightly praised for their ability to work efficiently towards their aim in the form of a project, to quickly set about working with problems and find shortcuts to solutions. The reverse side of this is that priority is not given to looking through the work process to find new ways of organizing work. The short-term perspective is applied here. Knowledge from experience, which is tied to a person, is in great favour while general knowledge, documented in writing, is found in the second place. Is the systematics and the methodical way of working required for information technology too unfamiliar to the Swedish construction sector? Do the companies lack this competence? Is good theoretical education of their employees not valued enough?

Newly graduated civil engineers, with up-to-date insight into current engineering science, are ordered to put on their boots and work on

building sites for three to five years before it is time for a career at the desk. Their fresh know-how, among other things of information technology, is already out-of-date before they can come forward and change the companies' way of working. Therefore, particularly interested civil engineers go for the computer industry and lose contact with construction.

On the architectural side the problem is partly different. The education in the universities of technology of graduate engineers and architects should rest on a basis of engineering science. However, architectural education is considered to be special, partly because it is very clearly aimed at training the students for a fixed profession, and partly because it is artistic to a considerable extent.

The education to become an architect is less built on a scientific basis than that required to become a graduate engineer. Many of the special subject representatives are practicians and the relationship of master-trainee is popular in the drawing halls. What is mainly transferred is knowledge based on experience. The share of systematically built up and theoretical knowledge is small. What counts in the schools is concrete examples, not structured, general knowledge. The architectural community is justly criticized for being too dependent on trends and fashion. Professionals who do not take theoretical schooling for their profession seriously are of course running the risk of having to live with constant jerks between different phenomena influenced by time.

Architectural research as a discipline is young. One of its aims is to build a theoretical basis for the profession. However, it has not yet got a clearly defined area as its research field and it has no scientific

methodology. On the contrary, it borrows very much from established disciplines and is in search of an identity.

There are similarities as well as dissimilarities between research and practice. The architect's every-day work is organized in projects where focus is on the result of this work and the quickest way conceivable to get there. The researcher often has practice as his research object and critically reflects upon the practician's way of formulating problems, searching for knowledge, organizing and carrying out his work. The researcher works straight across the projects and tries to see patterns and development trends. This is one reason why it is difficult for practicians and researchers to have an understanding of each other's way of working, in spite of the fact that they really have so much to give each other.

High production costs, symptoms of sick buildings, difficulties in meeting preset quality demands in construction and IT introduction are examples of phenomena which have, however, caused interest in research to increase. No possibilities can be seen to meet these complex questions within the frames of individual building projects. Multi-disciplinary knowledge is required and more and more practicians realize this. Maybe it is also here that we can find the answer to the question if the Swedish construction sector will be able to cope with IT.

The Swedish construction industry will be able to make use of the advantages of information technology if a concentration is made on the above mentioned knowledge and on employees well-educated for research and practice.

However, the companies in the construction sector are very varied. Construction companies are primarily directed towards production. Technical consulting companies are knowledge-based companies selling

advice. The management companies are service companies. Much of the work is and will remain a craft. IT is not of the same importance to everyone. People are in different developmental stages. Dr Matsumoto of the Japanese Institute of Technology, Shimizu Corporation, told me about construction robots. He meant that earlier many people outside Japan had shaken their heads and laughed covertly at the Japanese idea of using industrial robots on building sites. However, now they are real and carry out dangerous painting work, finish concrete surfaces and lift heavy burdens.

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Information technology straight across Swedish architecture and construction

The construction industry inevitably moves into the era of the information society. The biggest crisis in the Swedish construction industry of the twentieth century has not been caused only by the general decline in economy and a collapse of finance and real estate companies. Architects, constuctors and real estate managers have all too long clung to dated working methods. Anything built was possible to sell. This is no longer the case.

The construction industry is now facing a major change. The contours of a future, smart construction process may be envisaged. There, information technology will play an important part in binding together various competences in a construction network.

Computers are used today to draw, build and manage houses. But it is done in a way which is in glaring contrast to the possibilities offered by modern information technology. There is a wide gap between the development of modern IT tools for productivity improvement and quality assurance on the one hand and a beginner-like application in practice on the other.

Örjan Wikforss has written a book to provoke a debate on IT and the change in working methods which is now imminent. From the point of view of the architect he poses the question: Can Swedish architecture and construction cope with IT?

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