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FUTURE STUDIES IN CONSTRUCTION
INFORMATION TECHNOLOGY IN THE BUILDING INDUSTRY

Geert T.A. Smeltzer
Jan Dijkstra
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Information Technology in the Building Industry.
Geert T.A. Smeltzer.

Future Studies in Construction: Information Technology in the
Building Industry

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Introduction

This theme-report "Information Technology in the Building Industry" is a contribution to the study "Future organisation of the building process". This study is carried out by the CIB working commission W82 "Futures studies in construction".

CIB is a world wide organisation that is related to building and construction. This organisation strives at transfer of research results and co-operation between researchers. The working commission W82 has an international, multi-disciplinary and inter-professional scope on the future in construction.

The study is meant to develop scenarios for the future organisation of the building process and to produce a stimulating research report. The scenarios may become plausible realities in the year 2005.

This theme-report contains trends and developments for the implementation of information technology in the building industry (Figure 1). It will also contain potential consequences for a future organisation of the building process. It is based upon (inter)national inventories, brain-storm reports and some other papers.

In the study "Future organisation of the building process" the building process participants can be clients, architects, engineers, (sub)contractors and manufacturers that develop, construct and maintain building products. The building process consists of activities, tasks and roles of these participants during the initiative, program, design, construction, maintenance and demolition phases. However in this theme-report the emphasis is on the design and construction phase. Concerning the building process organisation this study deals with models for procurement, models and instruments for process management, tasks and roles of the various process participants and co-operation between process participants. In this theme-report "Information Technology in the Building Industry" the emphasis is on relevant building process participants, design, construction and management information, information technology as instrument, and on co-operation between the participants, using this technology.
1. Information technology in the building industry: an overview

1.1 Introduction

Technological developments are irreversible. Technological knowledge and possibilities can be enlarged, they cannot be diminished. It is certain that the building industry will be influenced by the information technology; however, it is uncertain how. Insight is necessary in processes and organisation of the building industry for a qualitative implementation of information technology. Additionally, insight into the information and techniques of the information technology is necessary for a productive implementation of information technology in time and costs.

State of the art

Information technology serves the production of design and construction information and contributes more or less to the productivity of design and construction processes. It does not really contribute to the improvement of the quality of the design or construction product yet.

Information technology replaces design instruments, such as drawing boards, model shops, calculators, and archives. It does not really contribute to the improvement of construction instruments or to the automation of design or construction processes.

Motivations for change

The possibilities to use information technology have increased. Still information technology hasn't been able to contribute to the building industry, or, even better, the building industry hasn't been able to gain advantage from information technology. Obviously there is a lack of influence in both ways. The building industry and the information technology need to develop their own scenarios and strategies (Figure 2). Together they have to agree upon feasible goals (Figure 3), relevant problem statements (Figure 4), and useful system specifications (Figure 5).

Building information is recorded in different ways. Besides the design models for CAD systems, there are geographical models for GIS systems, product models for CAE systems, production models for CAM systems and building models for FM systems. The availability of information technology will shortly lead to an information explosion. The fact that all buildings are unique and undergo constant changes over time contributes to this expectation. Next to actual management data and possible prospective design and construction data there should also be retrospective registration data in a building information system.

Effective integration and efficient communication of this immovable information are essential to a controllable information system, and should in the long run even lead to an information implosion.

1.2 Objectives

The objective of information technology in the building industry is to support the building industry and its objectives. To support the building industry, information technology should at least support the analysis of design and construction processes, the syntheses or decision making and the evaluation and presentation of the results. To support the objectives of the building industry, information technology should also contribute to the improvement of the quality of the design and construction product, and the productivity of the design and construction processes (Figure 3).

The quality of the design and construction product can be improved by the development of simulations for an enlargement of solution space, effective integration, product modelling, and automation. Information technology will be able to support the integration of information, and the simulation for design and construction processes. The building industry will have to define the product models with objects, attributes, operations, relations and messages for this integration and these simulations (Figure 4).

The productivity of the design and construction processes can be improved by the development of procedures for shortening the search path, efficient communication, process modelling, and automation. Information technology will be able to support the communication of information and the procedures for design and construction processes. The building industry will have to define the process models with activities, output, control, input and mechanisms for this communication and these procedures (Figure 4).

The overall mission of information technology, in addition to quality and productivity considerations, is a reduction of complexity and confusion inherent in the building industry. Programming, design, engineering, construction and management systems should be used during the increasing period of learning. Special attention should be paid to the ergonomical and economical aspects of these systems during the increasing
period of working. It should contribute to an improvement of the potential of the learning and working environment in the building industry.

1.3 Applications

Applications of information technology could make use of local and distributed computer systems, (tele)communication techniques and media. Examples of applications in the building industry show the use of local computer systems, and some hesitation in the use of distributed computer systems, (tele)communication techniques and other media. Some examples of application of information technology, related to the design and construction phases are:

Related to the design phase:
- text, data, drawing and image processing (word processing, databases, spread sheets, drafting and visualisation);
- geographical information systems (GIS);
- computer aided design (CAD, with a core role for project databases);
- computer aided engineering (CAE, design and simulation of structural and environmental control systems.

Related to the design and construction phases:
- costs and time planning;
- computer aided design/computer aided manufacturing (CAD/CAM, design for production);
- management information tools.

Related to the construction phase:
- numerical controlled machine tools (NC machines, a mature technology);
- flexible machining systems (FMS, essentially a number of NC machines connected by an automated materials handling system);
- robotics (common in some industries and some applications; difficulties will be encountered in more complex industries);
- computer integrated manufacturing (CIM, the realisation is slow, the needed multi-level standardisation of communication is still a problem).

The potential of information technology is constantly growing. Think for example of 3D modelling, object oriented databases and knowledge based systems. The application of information technology has however not progressed rapidly. This is due to confusion about the role and nature of information technology, and scarce research, development, education and training, application and management efforts.

Despite a growing number of Artificial Intelligence applications, its impact is still marginal.

1.4 Research and development

Research and development of information technology in the building industry is scarce. However, research and development is necessary to make the building industry gain advantage from information technology. Efforts are required to define feasible goals, relevant problem statements, and useful system specifications. Some general research and development subjects are:

Related to design and construction theories and methods:
- design and decision support systems;
- construction and decision support systems.

Related to information infrastructure (collected, processed (constructed, expanded, maintained, and modified), and disseminated information from international research and development work):
- process models (communication, interface and modelling);
- product models (exchange, models and simulation);
- presentation models (presentation, representation and perception).

Related to information systems and techniques:
- computer, and (tele)communication systems and techniques;
- audio/video systems and techniques and multi media (integration of computer, (tele)communication and audio/video techniques);
- presentation media (computer images, animation's, holograms) and Virtual Reality;
- hyper media (interfaces to data bases).

Related to standardisation:
- STEP/ CALS (research activities should stimulate an optimal monitoring and tuning of systems that allow problemless electronic integration of building product data);
- EDI/ PDI (research activities should stimulate an optimal monitoring and tuning of systems that allow problemless electronic communication between building process participants).

Related to system development methods and techniques:
- system analysis, system design, and prototyping;
- implementation of process, product and presentation models;
- implementation object oriented applications.

These research and development efforts should contribute to the improvement of the quality of the design or construction product, to the improvement of construction instruments and to the automation of design and construction processes.

1.5 Problems
The main problem statements and research questions are related to the building process organisation and to the implementation of information technology.

The question related to the building process organisation is: "How can the building industry gain advantage from information technology?"

The question related to the implementation of information technology is: "How will the building industry be influenced (changed) by information technology?" (Figure 2)

Other research questions are related to information and techniques of information technology in the building industry.

The questions related to the possibilities of information technology in the building industry are: "How can information technology contribute to the improvement of the quality of design and construction products?" and "How can information technology contribute to the improvement of the productivity of design and construction processes?" (Figure 3)

The question related to the limitations of information technology: "How can an effective integration and efficient communication be established?" or "How can an information explosion be prevented?" (Figure 4)

1.6 Approach
Due to the special nature of building information, the building industry should have influence on the development of building information systems. The fact that the technology push is greater than the market pull, does not relieve the building industry from its responsibility to design and develop its own system concepts. This requires insight into and a view on the development of information techniques in general and more specifically in the building industry. Research and development, education and training, application and management should be carried out as a joint effort of the building industry, information technology, and specialists in building information technology (Figure 8).

A design and construction language, with syntax, semantics and pragmatics, should be developed for the description of design and construction products, processes, and organisations. This language should also be used for the description of simulations and procedures. These descriptions should be used for the definition of design and construction theories and methods that are necessary for the development of systems and techniques (Figure 9).
The functionality of an information system is determined during the development of that system. The actual use can lead to ongoing but marginal improvements of this functionality. Besides that, the techniques of an information system will be adjusted to new technical developments. For example, existing features can be deepened, the working space can be enlarged, the speed can be increased, and the accuracy can be improved. Databases (input/output, source/destination) will be standardised for communication, software (control) will be systematised for automation, and hardware (mechanism) will be optimised for performance.

For the development of information systems, it is important that the information demand (output) will be determined first. Next it should be determined in what way this information is processed (control), what information is necessary for that process (input), and finally it should be determined which information technique (mechanism) is necessary or desirable. During the application of information systems it should be taken into account that the user of information systems or techniques will first choose the information technique (mechanism) that is offered; next the user will deliver the information that is needed (input), which will then be processed in an automated way (control) to a result that might be useful (output).
2. The building industry: process and organisation

Introduction
For a qualitative implementation of information technology in the building industry, insight is necessary in the building process organisation. Within the context of this theme-report the emphasis is on expectations concerning this building process organisation and more in particular on participants, information, instruments, and co-operation.

2.1 Participants
Building process participants can be clients, architects, engineers, (sub) contractors, and manufacturers, that develop, construct and maintain buildings. Here the emphasis is on the activities, tasks and roles of the participants in the design and construction phases in the near future.
The number of parties will grow due to specialisation. The significance of information technology as part of the finished building also grows. This brings new parties to the building process as system-specific expertise is demanded.
Offices of building process participants can be decentralised throughout the country, the continent or the world. Employers can work in office hotels (rented office space in anonymous buildings) (virtual offices). Industrial or building sites can be remote. Tele-communication and remote control systems can give the constructors the opportunity to stay up to date and to control construction processes (Virtual Reality).

Client:
- the number of parties answerable to the client decreases through co-operation/ co-ordination;
- the client will be more deeply involved.

Building process manager:
- emphasis on the productivity of the building process;
- more or less consistent relationship to client or architect;
- process and management of building process documentation (process models) and of building product information (product models);
- management of telecommunication, EDI/PDI;
- facilities for information services to other building process participants;
- management of Virtual Reality system and virtual office environment.

Architect:
- emphasis on the quality of the building product;
- changing rules, new materials, and modern techniques are of importance as a challenge for the architect, instead of precedents;
- little reuse of knowledge;
- design themes are ecology and multi functionality;
- the architect works in a more or less consistent relationship with clients (like an accountant);
- architectural offices specialise in objects or products;
- application of process and product models;
- design process with analysis of information, synthesis of design, evaluation of performance and presentation of results.

Analysis of information:
- statistical analysis based on documentation and databases;
- planning of activities, spaces, and facilities;
- Forecasting, backtracking, and goal seeking.

Synthesis of design:
- component based with design parameters and design rules. Dependent on the simplicity of the design problem;
- geometry, topology, and topography definition with time and attribute data.

**Evaluation of performance:**
- check list in combination with expert systems;
- simulations of objects and operations (states and transitions);
- simulation aspects are for example functionality, aesthetics, shape, environmental control systems, structures, construction, and demolition;
- prediction of operational costs by real-time simulations.

**Presentation of results:**
- presentation of specifications and results;
- only the government demands certain information;
- presentation techniques, like images, photomontages, animation's, holograms, and Virtual Reality;
- conversion and communication techniques are important.

**Engineers:**
- emphasis on quality of building product;
- design and consulting for the requirements of the building (activities, spaces, and facilities), structures and environmental control systems, cost estimation and planning;
- because of the integration of design aspects, the engineering offices integrate as well;
- facilities for research and development of simulation systems.

**(Sub) Contractor:**
- emphasis on the productivity of the building process, working circumstances, and logistical aspects;
- certification of products and of production, assembly, and maintenance procedures;
- a move from the building site to the industry, with an emphasis on logistical aspects and assembly of products;
- after mechanisation, slowly automation at the building site and flexible production in the industry;
- integration of product, method, and technique;
- limitation of number and kind of components;
- integration of industrial product design and architectural building design.

**Building information technology specialist:**
Building process participants, like clients, architects, engineers, (sub)contractors and manufacturers, shouldn't limit their activities, tasks and roles to the building process. In a joint effort with information technology and specialists in building information technology, they should also contribute to the definition of feasible goals, relevant problem statements, and useful system specifications to gain advantage from information technology. Together they should develop a design and construction language (with syntax, semantics and pragmatics) for the description of design and construction products, processes, and organisations. This language should also be used for the description of simulations and procedures. These descriptions are necessary for the development of information systems and techniques.

- emphasis on the development of reference process and product models and on communication protocols;
- attention for the level of knowledge of employers and employees;
- system development methods and techniques for technical information (design and management) and automation systems (construction, production and assembly);
- information and automation ask for systemisation, for a division in system parts and for a definition of discontinuity (from analogue to digital);
the measure of process support is a determining factor, but there is a lack of response to the economic and organisational interests of a company that invests in information technology;
- cost control and the acceptance of information technology can't be based on a technology push and there is pessimism about the effect of information technology in the market.

2.2 Information
Effective application of the information and the information technology is in all living areas essential in the information society. The transition process, from the industrial society to the information society, is much faster compared to the process from the agricultural society to the industrial society. The amount of jobs in agriculture and industry decrease and new jobs will emerge in information services, high technology creativity, human growth and in internationalisation. In the agriculture society land ownership was the decisive factor, in the industrial society it was capital, and information will become the decisive resource and competition factor in the information society.

Information is recorded in different data bases and in different information models, like design and construction models. This, and the fact that all buildings are unique and undergo constant changes over time, contribute to the expectation that the availability of information technology will lead to an information explosion.

Environment Model:
- available documentation about the soil and relevant surroundings of the building site.

Design Model:
- functional specifications;
- geometry, topology, and topography;
- numerical information (xyz), temporal information (process and attributes), and alpha information (operations and attributes);
- parts of the global design model replaced by product models during a design process;
- emphasis in product models is on technical specifications, appearance, process information, norms, certificates, etc.;
- building elements being functional components and building products being technical components;
- mainly used for simulation of design aspects with certified programs.

Construction Model:
- based on the environment model (building site);
- with product models of building site facilities;
- emphasis in process models is on logistical aspects, and on cost and temporal aspects;
- for the simulation of construction aspects, like cost and time plannings.

2.3 Instruments
There has been a development from power sources, to means of transportation, to communication techniques, to techniques for automation:
- 1750-1900 steam engine, railroad, and telegraph;
- 1900-1950 electricity, car, and telephone;
- 1950-19.. microelectronics, computers, and telecommunication.

There has been a development of instruments from computer techniques, to information techniques, to design, construction and decision support techniques.
There has also been a development of computer systems from application-oriented systems, to object-oriented systems. This could develop further to site-oriented systems and user-oriented systems.
Communication plays a central role in design and construction processes (sending and receiving design and construction information).
Instruments should help to improve the productivity of design and construction processes and the quality of the design and construction product. To improve productivity, the instruments should be based upon design or construction procedures. Quality can be improved by the use of instruments for simulations of design or
construction aspects. At the moment information technology is used to improve productivity and cut costs rather than to improve quality and add value.

**Instruments for quality improvement:**
- deficiencies in process, product, and project are easily accepted in the building industry;
- the application of quality assurance in design firms seems to be the topic for the future;
- performance concept (quality system, formalised procedures);
- from regulation to deregulation (retreating government, flexible production);
- the amount and complexity of decisions and choices increase and less time is available for the design and decision making process;
- design and construction models used for simulations of design and construction aspects with certified programs;
- ecology (measurement of the impact on the environment of building products and processes) and multi functionality are important new subjects;
- because of the location and functional program, every building process is unique. The unique part should be as limited as possible to get to a controllable process as soon as possible;
- rationalisation and normalisation of products.

**Instruments for productivity improvement:**
- rationalisation and normalisation of processes;
- operational models should be build and established prior to introduction of information technology.

2.4 Co-operation

The level of automation within the construction company, the architecture office, the engineering office, the suppliers, and the installation companies will rise in coming years. The highest rise shows itself in relation to products and services followed by the operational processes, the relationship between company departments, the contact with suppliers and clients, and management process. The least rise can be found in the relationship between companies that provide the same services. Although it is found that the introduction of information technology will lead to great changes in contacts with suppliers and clients, there seems no reason to give information technology a high priority for the coming years.

Even in the industrial society the building industry hasn't really addressed the issue of industrialisation. From the building site to industry and from craft to assembly, industrialisation is now seen as a crucial factor (more industrialisation). Standard processes and/or products require more consistent co-operation. There is a change from a capacity-oriented market to a product-oriented market with integral process management. The non-existence of dimensional and or modular co-ordination is seen as the main hindrance towards industrialisation.

**Co-operation** in the design, and construction phases will benefit from possibilities for an effective integration and efficient communication of information. This is essential to prevent an information explosion.

**Integration of information:**
- complexity means how much less the whole is worth than the sum of its parts;
- integration is how much more the whole is worth than the sum of its parts;
- buildings or parts of buildings as complete and consistent products (integration of products and of information technology).

**Communication of information:**
- active reduction of the mobility of people, traffic, and transportation (building as a regional activity);
- information systems need to be used to develop data transfer systems for all parties to keep them up to date on costs, schedules, quality and similar factors, despite their possibly different geographical locations;
- opportunity for referendums and for interactive consultation between people and decision makers are improving because of the development of information technology;
- communication systems for the connection of systems, installations, and equipment become wireless;
- telecommunication systems are to be used for the connection to services and employers;
- information technology is seen as a useful tool to facilitate a renewed construction process;
- information technology development slowly supports and links different phases of the building process;
- the use of information technology is no basis for the organisation of the building process.

2.5 Building process organisation

The traditional model of the building process organisation, segmented and fragmented as it is, no longer fits in its fast changing environment.

The traditional model of building process organisation itself is a major hindrance for the various interprofessional changes that are needed in today's building industry in various western countries.

To improve the overall performance of the building industry, the building process organisation must change. Short term improvements in the building process organisation must fit in the present structure of the building industry and therefore are more or less marginal. On the longer term structural improvements in building process organisation are possible, but only if combined with a more or less radical restructuring of the building industry.

The changes that will take place in the building markets are going to require that the organisation of the process puts an emphasis on:
- customer orientation;
- flexibility;
- specialisation;
- networking;
- introduction of new skills and expertise;
- emphasis on the final product instead of production;
- international know-how in purchasing products and services.
3. Information technology: information and techniques

Introduction
To make the efforts in the implementation of information technology productive in time and costs, insight is necessary into the information and techniques of the information technology.
The potential of information technology is constantly growing. The application of information technology has however not progressed rapidly. This is due to confusion about the role and nature of information technology and scarce research, development, education and training efforts.

3.1 Role and nature of information technology
The role and nature of information technology should contribute to its overall mission. The overall mission of information technology, in addition to productivity and quality considerations, is to reduce complexity and confusion, as is inherent in the building industry.
Information technology is the science of the development of information techniques and its use. It goes a lot further than simply using computers as a calculator, or the computerisation of the administration. Information technology contains the knowledge that is used when changes in the information techniques have to be made of use. Information techniques influence the information supply of an organisation, and also the communication techniques (computer and telecommunication systems).
Means of communication are added to computers and instead of computerisation we prefer informatisation.
The computer’s memory becomes more important than its power of calculation and instead of computer science, we prefer computing science or information techniques. Thanks to chips, computer characteristics can be built into devices and machines and the computer is replaced by an information system that acquires, processes and stores data, and provides information for the organisation. An information system can lend support in the comprehension of a design or the control of a construction process.
An information system is a system in which automatic data processing plays an essential role for information supply and information organisation. An object system is a described occurrence in reality that is of interest for an organisation. An information system supports an object system for the acquisition, processing, and supply of information. An information system supports the knowing or controlling of an object system by employees of an organisation.
Knowledge is necessary about computers, and programming, and about the use of computer systems for the supply of information in an organisation. Because of computers, more information is available to users. In organisations computers and their applications are new constituencies at different levels of policy making and management. Computers and their applications demand changed structures of the organisations of the information supply.
Information technology makes better infrastructures for common social interaction, especially by combining computers with communication media. To express that information technology means more than “the same as before”, the actual state is called the information society.

3.2 Social aspects
From research of social changes, it seems that:
- the inclination to apply new technological developments decreases as the tempo in which they become available increases;
- changes that are too fast produce their own resistance;
- technological developments are irreversible;
- technological knowledge and possibilities can be enlarged although they cannot be diminished.

3.2.1 Automation, work, and organisation
In the beginning there was no interest for the influence of technology on the quality of labour. Now there is considerable attention for subjects like:
- quality of labour;
- organisational structures and processes;
- experience of the working situation;
- communication and decision making processes;
- position of management;
- qualification for certain functions.

3.2.2 Technology, organisation, and labour

Technological developments are independent variables that can determine employment and the organisation and quality of labour. These factors adjust to the technological developments without being able to influence them in a determined way. Since the '70's, there has been an inclination to give directions to technology from the labour organisation and the workplace.

3.2.3 Automation and productivity

The use of information technology has influenced the primary and supporting processes in an organisation. Information technology has an effect on the substance and the kind of work, and on the values and norms that are considered important in an organisation. Investments in computer and communication facilities are justified with a view on higher effectiveness, increased efficiency, and improved products and production processes.

The performance potential in terms of quality and productivity of product and process, the quality of labour, the potential to compete, and the profit capacity of information-intensive companies can be strengthened by wider and better use of computerised information and communication systems. Research has shown that productivity improvement is mostly not realised because the existing organisation was not prepared for automation.

There is a gap between the technological possibilities of an organisation and the potential of that organisation to incorporate that technology. Research should aim at the quality of the organisation, and at the management that should direct this quality.

3.2.4 Automation and employment

Optimists state that labour saving technologies by themselves can not cause unemployment in the long term. On the contrary, the application of new information and communication technology will lead to new products and services, to new markets, and consequently to new workplaces.

Traditional industries will, however, certainly lose workplaces, not only because they do not use new technology, but even more so by the transferral of their activities to lower wage countries. (Of course this will be more difficult in the building industry)

Pessimists state that when economic growth is absent or is decreasing, the replacement of labour by capital goods can not be compensated by the growth of volume or an increase in the demand for new goods or services.

3.3 Automation as a growth process

The application of modern information and communication systems has been less revolutionary than expected. There is in fact more of a gradual growth process where traditional mechanical tools are replaced by computerised counterparts. Research has shown that organisational changes only then take place when a new infrastructure is implemented. It appears that the organisation follows the technology. This growth process (H.J. Bullinger, Fraunhofer Institut fur Arbeitswirtschaft und Organisation) has different phases:

Starting phase:
- introduction of new systems happens in an uncoordinated manner;
- because of the lack of planning, there is room for local initiatives;
- users only explore new systems rather than using them;
- considering the labour organisation, ideas about labour diversification, labour distribution, and labour specialisation predominate;
- efficiency measures (time and cost reduction) have the upper hand;
- management is hardly interested.

Expansion phase:
- more technological equipment appears in the workplace;
- the possibilities of new technologies are accepted;
internal networks appear incidentally;
- the need for integration of different applications begins;
- the problem is that the organisation follows the technique;
- there is a great chance that conflicts will arise between specialists in the area of information technology, and experts in organisational structures;
- management gets attention for the need to set out new career perspectives for involved employers that are interested in the use of new technologies.

**Formalisation Phase:**
- process automation proceeds and it becomes appropriate to pay more attention to the organisational effects of the available systems;
- experiences with the use of networks point out that a large number of functions can be decentralised;
- staff and managers start to use systems themselves for the support of policy making;
- there is a growing interest in the other dimension of productivity, namely effectiveness (more effective organisation, greater flexibility, and quality of products and services);
- formalisation expresses itself in the agreement of standards concerning the execution of labour; a danger exists for bureaucracy, a blockade of creativity, or the initiative of employees.

**Integration Phase:**
- integration of information and communication systems;
- gradually technique comes in second place and the organisation comes in first;
- instead of the users, new specialists will take care of the technical infrastructure;
- automation occurs at all levels of the organisation;
- if the technical integration is realised, there will be the possibility of functional integration aimed at process integration.

**Maturity Phase:**
- the process of innovation gradually becomes comfortable at a higher technological level;
- the introduction of fifth-generation systems allows technology to control more complex processes;
- gradually the content of processing has moved from data processing to information processing, and eventually to knowledge processing;
- concerning control and planning, there arises a need for information resource management;
- the symbiosis of valuable labour forces with valuable technology can stimulate the process of decentralisation; decentralisation can create more autonomy in the workplace where small self-supported work units take the place of formal hierarchical departments;
- the intelligence of the workplace is increased by the possibilities to use various kinds of expert systems.

**3.4 Application of information technology**
Examples of applications in the building industry show the use of local computer systems, and hesitation in the use of distributed computer systems, (tele)communication techniques and other media.

**3.4.1 Information:**
- data, information (facts), rules, and knowledge;
- knowledge is information with rules concerning objects;
- objects (entity, level, and complexity), function (attribute, domain, and functional aspects), and state (phase, temporal aspects);
- geometry (measure), topology (shape), and topography (location);
- retrospective information (registration and reproduction);
- prospective information (production and presentation);
3.4.2 Information system:
Development or history (technical and functional):
- application-oriented approach (participant oriented, emphasis on procedures);
- data-oriented approach (project oriented, emphasis on integration);
- object-oriented approach (product oriented, emphasis on simulation);
- state-oriented approach (process oriented, emphasis on communication).

3.4.3 Information techniques:

Hardware:
- computers, peripherals, and media (communication techniques, systems and media);
- numerical control systems, robotics, flexible production automation;
- the functional complexity of hardware parts increases; software is becoming integrated;
- integration of documentation, audio, video, and information in one single medium with an integration of several media in one medium (multi media);
- media are interactive with stereo audio and stereo video;
- integration of media with a real-time medium with an emphasis on real time response to user stimuli and vice versa (Virtual Reality);
- a real-time medium is dynamic with surround audio and surround video (super computing);
- PC diversifies itself to a Project Computer (multi tasking, multi user), and a Personal Communicator (multi-tasking, multi site) (electronic highway, digital highway).

Software:
- information and knowledge processing;
- component and rule-based, object oriented.

Databases:
- databases in an engineering environment will be 3DAT databases (3 Dimensions, Attributes, and Time);
- multi-user, multi-site databases (distributed databases for concurrent engineering).

3.4.4 CAD/CAM
CIM is meant when integration of different functions of an organisation (such as marketing, design, production, and service) is strived for (concurrent engineering).
CAD/CAM should lead to flexibility with shorter run-through times, small series, low supplies, short product life cycles, and fast delivery times. Computers can contribute to this flexibility because they can be programmed.

CAD purposes:
- increase productivity of design and management by automation of routine tasks and by simplification of modifications
- improve control of the complexity by computer-aided simulation and management
- speed up the design process

CAD functions:
- offering of component data base, containing shapes and attributes of components and with query functions
- analysis, layout, simulation, comparison, control, documentation and presentation

CAM purposes:
- save labour by computers that can take over certain tasks
improve processes by speeding up the tempo, limit process failure, and make tolerances smaller
add flexibility by programmable control with shorter changeovers, shorter run-through times, better insight in order status, and shorter and more accurate delivery time

CAM functions:
- physical control by integrated systems in machines and instruments (numerical control and robotics)
- operational control by co-ordination between different processes and their preparation
- control functions by evaluating process states against certain norms and generation of control assignments (measure and control)
- registration function by observing and recording process states and analysing and aggregating for control functions

3.5 Research and development, education and training
Research, development, education and training efforts should improve the potential of the working and learning environment. It should improve design, and construction instruments. It should also contribute to the automation of design and construction processes.
The life cycle for skills is getting shorter. It is getting shorter than the employees "working" life. The only way to prevent this is to slow down the developments of information technology or the stress the skill life cycle by continuance education and training.
Some relevant research subjects are:
- EDI/PDI;
- product models;
- Virtual Reality.

3.6 EDI and PDI in the building industry
The building industry is characterized by the development of unique projects on various locations with dynamically changing cooperation between participants.
In this situation is clear that the information-exchange between different participants plays an important role.
Traditionally, the exchange of information, e.g. offers and orders, and the questions for product and price information, employs personal contact, mail, telephone, telex and telefax.
The development of data exchange is, through the introduction of electronic communication, evolving rapidly.
Digital data is the keyword in electronic communication. This data is built using the computer in a traditional way, resulting in different digital documents such as: invoices, transport orders, drawings, etc. The delivery takes place using a diskette by mail or telecommunication based on digital network connections.

3.6.1 Electronic communication
The development of information technology and electronic communication is rapidly evolving in such a way that the creation of documents will become obsolete. Not the digital document, but merely the relevant data from this document will be sent using telecommunication.
Not only will the technical facilities become available, but also the knowledge and experience using this technology. Improvement of communication is an important stimulant and as a result improved data exchange will be made possible.
In order to be able to communicate electronically, computer systems should be able to understand each other's data bases. In order to achieve this agreements and standards are necessary.
Computer systems should be equipped with facilities to create digital databases, to send, to receive and to use for further transactions.
Electronic communication should not be restricted to computer systems of the same kind. It should also take place between different computer networks.
The data can be summarised as follows:
- the envelope; containing information about sender, recipient and date of transmission etc.;
- the message context; type and function of the data base, the description of tasks expected from the recipient;
- message content; one (or more) data base(s).

In the building industry two types of data can be differentiated:
digital data in which materials, working-stock, labour, building products, building materials etc. are specified within the context of a business transaction. A digital order contains information for the delivery of a number of building products of a specified quality and type;
- digital models describing products or processes and/or kinds of technical information (drawings, details etc.).

The developments, on the types of data is for a substantial part based on communication protocols, like:
- EDI: Electronic Data Interchange;
- PDI: Product Data Interchange;

### 3.6.2 Strategic importance

EDI/PDI is of strategic importance because it offers the building industry an IT-infrastructure which can be used by all involved participants to communicate electronically. By increasing the support for customers a competitive advantage is offered. If not applied in time the lack of IT-development will result in a disadvantage position related to other competitors.

EDI/PDI contribute to several strategic goals:
- time to market;
- fast and "Just in Time";
- concurrent engineering
- co-makership

Besides strategic advantages EDI/PDI also has an influence on efficiency. Several potential advantages of efficiency are:
- paper reduction: orders, invoices etc. need not be printed any longer;
- reliability: elimination of plural input increases accuracy;
- interpretation: the number of misunderstanding decreases by using standards and agreements;
- administrative transactions: manually administrative transactions will be reduced;
- availability: EDI/PDI are always operational 24 hours a day all over the world;
- EDI/PDI accelerates the communication process because of the lack of human interference.

### 3.6.3 EDI

EDI focus on electronic communication between computer systems that support business transactions. The digital data which is exchanged is called an **EDI-message**. An EDI-message contains standardised types of data in which the domain is described; and the syntax and semantics of the data are pre-defined. EDI uses standards such as ISO-EDIFACT (Electronic Data Interchange For Administration, Commerce and Transport).

The different types of EDI-messages which are developed for the building industry are: order, shipment, acceptance and invoice messages.

### 3.6.4 PDI

PDI focus primarily on electronic communication between computer systems that support technical business processes. The content of the message is sent without envelop and context. Differentiation is made in:

- **PDI-document**
  - This is data based on files. Typical PDI-files are technical drawings and technical product information.
- **PDI-model**
  - Data is based on a model, not on files. Typical PDI-models are geometrical and product models.

A system that supports technical business processes should be able to extract information, like quantities and geometry from an electronic drawing. PDI-documents and models contain standardised information in which the domain is described; the syntax and semantic are not pre-defined in advance.

PDI used standards like STEP (STandard for the Exchange of Product model data). Operational PDI documents and models operational in the building industry are: technical drawing, quantity lists, 3D wireframe presentation, parametric model of construction elements like prefabricated concrete elements and results of technical calculations.

### 3.6.5 EDI/PDI

EDI and PDI are related to each other:
- in the context of transactions descriptive information is exchanged in addition to specifications;
- the specification of building materials, products, etc. is exchanged in addition to descriptive product data.

Because of this overlap there is a growing need for using EDI/PDI together including sharing the same infrastructure. EDI and PDI, originally two separate developments will therefore be highly integrated developments in the future.

These developments will be realised in three phases:
- short term:
  EDI and PDI will support each other (1-2 years). In this way the structure of the EDI-message can be used to support PDI-documents and models;
- medium term:
  EDI and PDI will develop in parallel (3-5 years). Mutual integration of EDI and PDI based on common vocabulary, and standards;
- long term:
  EDI and PDI are integrated (> 6 years). EDI and PDI will be integrated on the basis of data models of different product types (e.g. buildings, ships).

The integration of EDI and PDI is of strategic importance because data exchange contributes through fast exchange without failures to the improvement of the competitive position of the company.

3.6.6 Implications for the building industry

Future Information Technology-developments, especially EDI/PDI developments, offer many advantages for the building industry.

EDI/PDI makes it possible to exchange information fast without failures, and without loss of semantics. To improve electronic communication the following questions must be answered:
- who defines the content of a message and when?
- what product type is described?
- what is the status of the message? (concept, accepted by whom and when)
- are the latest modifications processed?
- is it a new version?

Product Data Management (PDM-techniques) concentrate on answering these kind of questions. PDM concentrates on the quality of the product(ion), and on the management of processes during the life-cycle of the product.

3.7 Product modelling

The basic concept behind PDI as well as PDM is that a product such as a building, or a part of a building, can be seen as a result of a design, construction and manufacturing process. This result, or product, is the outcome of a value-added chain of several production processes, where different parties are involved. Collaboration in this overall design, construction and manufacturing process is far from efficient and effective. It is rare that information produced in digital form by one participant can be used directly by the information systems of other participants. This is due to several factors in different domains. Some of these are:
- the complexity of the building product and construction process;
- the lack of standards;
- the lack of insight in modelling information including semantics;
- the traditional nature of the building industry.

Various attempts have been made to improve this situation. The use of neutral file formats for exchanging geometrical information does not fulfill today's demands for general product information. Not only the geometry is exchanged during design, construction and manufacturing; all kinds of information needed by the different participants are exchanged too. Nowadays communication demands a new definition of standards and protocols concerning the contents of the information to be exchanged. An important part of the standards is the formal description of the data. Data structures for the description of product definition data is referred to as 'product models'. So a product model (PM) is a conceptual description of a product, which can be used as an information base for all processes involved in the design, manufacturing and use of that product. If the product is a building, the product model is called a building model.

The term 'conceptual' is derived from the ISO-ANSI/X3/SPARC three layer schema. This schema, or model, recognizes the next three layers:
- the internal level;
- the conceptual level;
The essence of this architecture is that one conceptual data description can result in more than one implementation and interpretation resulting in two types of independence, namely, view - and data independence. In a conceptual model only the information itself (semantics) is considered, not the format (syntax) in which the information is stored.

The research and development on product models is strongly based upon the theory of database management systems. Underlying all database systems are data models. Like a data model, a product model is characterized by:

- a collection of data structure types or data objects including their relationships;
- a collection of operators or rules, which can be applied to validate instances of the data objects;
- a collection of general integrity rules, which implicitly or explicitly define the set of consistent, states or changes of states, or both.

Important in product models is the treatment of semantics and data abstraction. The following two abstractions are essential: aggregation which abstracts a relationship between objects to a higher level aggregate object, and generalization, which abstracts a number of common characteristics to a higher level generalized object. The semantics or 'meaning' of information should be without misunderstanding to all parties during the complete product life cycle.

### 3.7.1 Developments

Research, to the end of the 1980's, was concentrated on the development of one large and complex building model in which not only product information, but also production information, is modelled. Several efforts in that direction showed that one model was not achievable. Today's research focus on the exchange of information is based upon several product models (views) between information processing systems. In this area most of the extensive work is being carried out in the ISO-STEP research. Although some results have been achieved, operational systems based on these results have not yet been built and there is still a long way to go.

The primary bottleneck at this moment is the urgent need for standardization of all data structures including their semantics. Other bottlenecks are: the lack of insight of top management in the building industry into the possibilities of information technology and the lack of proper tools to perform data analyses and design.

### 3.8 Virtual Reality

From 1991 work has been carried out in research into and development of Virtual Reality in the building industry. Work has been carried out on computer-generated stereo images and animation and on known Virtual Reality technologies such as sensors, head mounted displays, joysticks, control systems and transputer-based computer systems.

The difference between other presentation media and Virtual Reality is determined by the use of the representation. Presentation media can reproduce a design model with the aid of a representation which has been worked out beforehand, whilst Virtual Reality can be used in order to perceive the model oneself by means of a representation which is worked out on the spot and at once (in real time). With the use of presentation techniques the emphasis is on the presentation of a design while in the case of Virtual Reality the emphasis can be placed on the evaluation of the design. This is why presentation techniques are discussed in terms of a target and a targeted group whereas in the case of Virtual Reality what is discussed is a result, that is to say the design model in Virtual Reality, and a user.

#### 3.8.1 Virtual Reality in the building industry

In relation to the research into Virtual Reality the assumption was that this technology should be able to make a contribution to the building industry. Through the use of a simulation of the behaviour of a design model, in stead of for example rules of thumb, the problem-solving capacity of the designer can be increased. This must lead to an improvement of the quality of an architectural design. The use of 3 dimensional design models, for an efficient exchange of data during the design process must lead to a reduction in the path which has to be covered in order to produce a satisfactory design. This means that a contribution can be made to the improvement of productivity in relation to the architectural design process. The use of a simple user interface, such as is possible in the case of Virtual Reality, should contribute to the quality of the design, the productivity of the design process and also to an improvement in working conditions.

The research into the use of Virtual Reality in the building industry should contribute to an improvement of theories, technology and applications of Virtual Reality. Here the building industry has specific requirements.
With regard to the subject of interfaces the building industry has soon specific requirements because those involved in the building industry range from lay people (principals, consumers) to specialists. With regard to the use of models, digital models of buildings are of great importance owing to the lack of other types of prototypes. Finally, with reference to the representation of these models specific requirements are set because the building industry is so close to everyday reality for everyone.

Owing to the importance of the interface, the model and the representation these subjects have gradually become included within the research into a Virtual Reality system concept

### 3.8.2 Virtual Reality system concept

This concept brings together the various components and possibilities of a Virtual Reality system. In this concept different stages of development are brought together at the same time.

The system concept consists of the following components:

- an interface between the person and the computer for the modelling of the design;
- possibilities for the modelling of the design
- a design model;
- possibilities for the simulation of the design model;
- a representation of the results of the simulation;
- possibilities for the perception of the representation;
- an interface for the perception process (Figure 10)

Hereinafter these different components will be looked at in more detail. On the one hand there will be a brief mention of the most important items which constitute an outside influence on the component. On the other hand the characteristics will be named which are typical for one of the development stages. Other aspects which are regarded as being relevant will finally also be added to the description of the components.

### Interface

What is involved here is the interface between a user and the computer system. The user can for example be a principal, an architect or an adviser. A computer system consists of (peripheral) hardware, software and data elements. For the use of this it is above all the possibilities of the peripheral hardware and the software which are of importance. The interface has to operate within the system concept as well as with the modelling in addition to the perception aspects. Clearly differing points of departure apply for the software for this. Besides this various peripheral software is available for the modelling or the perception.

Various actors can be incorporated for the modelling. Here it is being assumed that the modelling is effected in the first place with the hands. For this use can as appropriate be made of a traditional keyboard or of a normal mouse. A Virtual Reality system offers in place of this a mouse, joystick or spaceball with a minimum of 3 (3D) but better with Virtual Reality (6D) levels of freedom. In combination with sensors, which can measure all translations (3) and rotations (3) of the hands and individual function keys it is possible to manipulate the individual model components. With what is referred to as a data glove it is possible to replace the function keys with gestures or actions. The voice may also be used for modelling. With the aid of spoken commands (voice input) certain tasks can be given and in some cases the entry of data is also possible. The use of the eye for the manipulation of a design model appears to be unreal. Various military applications in fact already make use of what is referred to as eyeball tracking, or else the measurement of the direction of perception by the eye. With this measurement data it should for example be possible to move or to displace certain model components.

Various sense organs can be used for the perception process. Here it is being assumed that perception takes place in the first instance with the eyes, that is to say by means of sight. For this it is possible to make use of a traditional screen. A Virtual Reality system offers in place of this a minimum of a stereo screen, what is referred to as a head mounted display or a stereo-large image projection in for example a dome (or a cave). By means of sensors, which here too can measure 3 translations and 3 rotations, it is possible to perceive a representation of a design model. If the sensor is for example fixed to the head mounted display then all movements of the head can be measured and at almost the same time the corresponding representations can be worked out. Naturally it is also possible to use the ears or hearing for perception. With the aid of acoustic simulations, background noise for the purposes of illustration or spoken commentary a representation can be noticeably improved. Noise can, for example in an immersive system, also be used in order to improve the
orientation of the user. The use of for example the hands, or of touch, for the perception of a representation has already been applied in combination with a data glove.

This possibility is in general designated with the terms tactile feedback or force feedback.

The design for and the realisation of an interface is dependent on the form of communication between the system and the user and mutually between the users. In addition to a definition of the form of communication a definition in terms of the model (process model) of the process in which the system is to participate is also necessary. It must be possible to develop an interface on the basis of these two things.

The character of the interface is also developing itself still further. Until recently, and this still applies for presentation media, user-friendliness was an important characteristic feature of a computer system. In a Virtual Reality system the interface has rather to be as natural as possible. This is, amongst other ways, attained by means of sensors for the head and hands. At the same time the interface is progressing from being interactive, with a sequential connection between question and answer or between measurement and regulation, to acting in real time, with a connection which is as good as being parallel (or dynamic) between these.

**Modelling**

Here this concerns the modelling of a design model. Here the emphasis is clearly on the generation of a design. The form of this is dependent on the phase in which the construction process or the design process finds itself and on the design methods or systems which may be available. The aim of modelling using Virtual Reality is in particular the reduction of the research time and thus the increase in productivity of the design process. During the modelling attention must be paid above all to the consistency of the model. At the same time consideration has to be given to the temporal aspects of the model components.

The design for and the development of the modelling components of a Virtual Reality system are to a great extent determined by the available technology for this.

For modelling, the current starting point is the modelling of elements of buildings in the form of components. These components can be looked up in a component library. From then on they may be used in the composition of the design model. Due to the possibilities of the Virtual Reality systems the components which have geometry and attributes have to be replaced by objects. Objects are in this case a sort of component but they have mutual relationships and individual operation which describe their behaviour under certain circumstances. Finally certain situations of the objects have to be used for the composition of a design situation.

**Model**

This concerns here a model of a design (object), in a situation (space), at a certain moment (time). The geometry and the attributes of the entities are given from the design or the object. In the case of construction the objects can be divided up in terms of area, construction and construction element levels. Geographical and topological relationships between the entities can be established in the situation or the space. Taking into account the time aspects, the operations of certain objects can be established in a retrospective, current or prospective sense. Through this several versions of the situations of these objects arose.

The design for and the realisation of a design model (structure) is dependent on the form of the exchange of data between the different systems. In addition to a definition of the form of the exchange a definition of the product in model terms (product model) is also necessary.

The character of the design model is also still undergoing further development. Until recently, and this still applies for presentation media, if a model was 3 dimensional this was an important characteristic feature. In a Virtual Reality system the model has rather to be as autonomous (independent) as possible. This is, amongst other things, attained by the use of objects with operations instead of components with applications. At the same time the design model is progressing from being integrated with a sequential connection between different aspects to acting in real time, with a connection which is as good as being parallel between these.

**Simulation**

Here this concerns the simulation of certain aspects of the design model. The emphasis here is on the evaluation of a design. The form of this is dependent on the architectural aspects such as lighting, which have to be simulated and on relevant information technology (building information theory) aspects.
The aim of the simulation in Virtual Reality is in particular the increase in the capacity for the finding of a solution and thus of the quality of a design. During simulation attention must above all be paid to the correctness of the result. At the same time consideration has to be given to new developments in the area of for example concurrent engineering.

The design for and the development of the simulation components of a Virtual Reality system are to a great extent determined by the systems which are available for this.

In the case of simulation, the starting point at the current time is the simulation of the attributes of design components, such as colour and texture. Due to the possibilities of the Virtual Reality system the simulation of component attributes has to be replaced with the simulation of operations of objects. Finally transformations of model situations have to be simulated.

**Representation**

This concerns here a representation of a design model or else the result of a simulation of one. A representation can be graphic (for example audio / video), alphabetic (for example text) and / or numerical (for example tables) in nature. What happens in most cases is that the representation of a design, in Virtual Reality, is able to make use of light, sound and touch.

The design for and the realisation of a design representation depends on the form of presentation to various users or interested parties. In addition to a definition of the content of the presentation a definition in model terms (presentation model) of the required or necessary presentation is also required.

The character of the representation is still undergoing further development. Until recently, and this still applies for presentation media, representations were generated on the basis of certain raytracing algorithms. In a Virtual Reality system the representation has rather to be as realistic as possible. This is, amongst other things, attained by the use of raydiosity or ray tracking algorithms. At the same time the design representation is progressing from being iterative (repetitive), with a sequential connection between changes and representations, to acting in real time, with a connection which is as good as being parallel between these.

**Perception**

Here this concerns the perception of the representation. The emphasis here is on the analysis of a design (or a design situation) The form of this is dependent upon the (detail) level in which the design model (and the representation) is to be found and the relevant elementary geometry aspects. The aim of the perception in Virtual Reality is in particular the improvement of the “conditions of work” for, by way of example, the principal, the designer and the adviser. During perception attention must above all be paid to the completeness of the design model and the representation. At the same time consideration has to be given to new developments in the area of distributed data bases.

The design for and the development of the perception in a Virtual Reality system is to a great extent determined by the available media.

In the case of perception, the starting point at the current time is the perception in the form of a mono image and sound.

Owing to the possibilities of Virtual Reality systems the perception in mono has to be replaced with perception in stereo, which applies for both the image and the sound. Finally it must be possible to perceive design presentations with satisfactory quality and speed by means of immersion (surround / all round).

### 3.8.3 Stage of development

With the aid of system concept components it is as a result also possible to describe the situation with reference to the development of presentation media into Virtual Reality. Here it is being assumed that Virtual Reality actually stems from presentation media. The most important difference between the two media is once again the fact that in the case of presentation media the emphasis is on the reproducing of a representation of a design model whilst in the case of Virtual Reality the emphasis is on the (self) perception of this. Another difference is that in the case of presentation media there is a mutual interface between people and that in the case of Virtual Reality the interface is between the person and the computer system.

**Presentation media:**

The situation with regard to presentation media can be demonstrated by means of the following characteristics:

- user-friendly interface;
- modelling with components;
With reference to Virtual Reality systems a difference is made between Stereo Virtual Reality systems and Immersive Virtual Reality systems. The situation with regard to these systems can also be demonstrated by means of the system concept.

**Stereo Virtual Reality:**
This designation refers to the use of stereo images and the possibility of perception with stereo glasses (polarised glasses or shatter glasses). These systems are also designated partial immersive Virtual Reality systems or virtual holography systems. In their application the emphasis is on the design objects. In this way a comparison may be made with working with a scale model or a mock-up.

The situation with regard to stereo Virtual Reality can be demonstrated by means of the following characteristics:

- natural interface (with sensors);
- modelling with objects;
- autonomous design models;
- simulation of operations;
- realistic representation;
- perception in stereo Immersive Virtual Reality.

**Immersive Virtual Reality:**
This designation refers to the use of immersive (surround / all round) images and the perception possibilities with head mounted displays or stereo data projection in domes (caves). These systems are also designated as full immersive Virtual Reality systems or virtual environment systems. In their application the emphasis is on the presentation. In this way a comparison may be made with working with a 1:1 model or prototype.

The situation with regard to immersive Virtual Reality can be demonstrated by means of the following characteristics:

- interactive interface;
- modelling of situations;
- integrated model;
- simulation of changes;
- iterative representation;
- perception with immersion (head mounted display, dome).

### 3.8.4 The Future

Within a short time the developments with reference to the expansion of the interface should be completed. Here this concerns an expansion in order to attain the facilities of modelling and perception. With regard to modelling the use of the the 3D / 6D spaceball / joystick should be expanded upon with the use of audio / voice input. The use of eyeball tracking, for example the “looking at” of an object in a model is not yet envisaged. With regard to perception the use of 3D / 6D (head) mounted displays and sound for illustration and orientation can be expanded upon with the use of tactile feedback. By means of this, the three, in this case, most important sense organs should be able to be used for modelling and perception.

In the near future further work should be carried out on the ultimate Virtual Reality system. Here what is to be attempted is the creation of a real time computer and communication system. This system should offer possibilities for an interactive interface, for the modelling of model situations, for integrated design models, for the simulation of changes in situation of the model, for iterative representations and for the perception of these representations with immersive (surround) media.
In the near future research projects, should become directed to the research and development of possibilities for the simultaneous use of the same Virtual Reality system by several users (multi user) and for the simultaneous use of the same design model at several locations (multi site). This research is to be followed by the development of a prototype Virtual Reality system for the architectural design process. This prototype should first be intended for presentations and demonstrations in general and within the construction industry in particular.

The expectation for the near future is that the interface of Virtual Reality systems should become more interactive. The model be made integrated in character and the representation should be more iterative. Finally it should be possible to process the interface, the model and the representation in real time. These important system components should thus imperceptibly overlap with one another.

Because the current situation is already designated with the term Virtual Reality perhaps the situation in which the different system components merge in with one another should be designated with the term Artificial Ontology.
4. Information technology and the building process organisation: trends and developments

Introduction
This theme-report contains trends and developments for the implementation of information technology in the building industry. It will contain potential consequences for a future building process organisation. It is based upon a distant view on the building process organisation and on a closer view on the information technology (Figure 1).

This theme-report should also address the research questions that were put forward.

First of all there was a question related to the building process organisation: "How can the building industry gain advantage from information technology?" And there was a question related to the implementation of information technology: "How will the building industry be influenced (changed) by information technology?" (Figure 2)

Secondly there were two questions related to the possibilities of information technology in the building industry: "How can information technology contribute to the improvement of the quality of design and construction products?" and "How can information technology contribute to the improvement of the productivity of design and construction processes?" (Figure 3) And there was a question related to the limitations of information technology: "How can an effective integration and efficient communication be established?" (Figure 4) or "How can an information explosion be prevented?"

Due to the special nature of the building process organisation, these questions should be answered in a joint effort of the building industry, information technology, and specialists in building information technology. Therefore a design and construction language should be developed for the description of design and construction products, processes and organisations. These descriptions should be used for the definition of design and construction theories and methods that are necessary for the development of information systems and techniques. (Figure 9)

4.1 Trends and developments for the implementation of information technology

The application of information technology is less revolutionary than expected. There is in fact still a gradual growth process where traditional mechanical tools are replaced by computerised counterparts. The building industry has overcome the Starting phase with an introduction of new systems happening in an uncoordinated manner. It finds itself between the Expansion phase, with more technological equipment in the workplace and an acceptance of new technologies, and the Formalisation Phase, with proceeding process automation, more attention to organisational effects and the use of networks and decentralised functions. This phase will eventually be succeeded by the Integration Phase, with an integration of information and communication systems, and the Maturity Phase, where the process of innovation gradually becomes comfortable at a higher technological level.

Insight is necessary in the organisation of the building process for a design of information systems and for a qualitative implementation of information technology. The use of information technology, in relation with the building process organisation, should be aimed at an improvement of the quality of the building product. Therefore information technology should support simulations of design and construction aspects, integration of information, product modelling and automation in design and construction information systems. This support is dependent of the advantage the building industry is able to gain from information technology. It is limited by the confusion that exists in the building industry and the scarce research and development and education and training efforts and facilities.

For the realisation of information systems and for a productive implementation of information technology in the building process organisation, insight is necessary in information techniques. The use of information techniques should be aimed at an improvement of the productivity of the building process. Therefore information technology should support procedures for design and construction processes, communication of information, process modelling and automation of design and construction processes. This support is dependent of the influence of information technology on the building industry. It is limited by the complexity of the building industry and the existing application and management environment.

4.1.1 Quality of design and construction products

Information technology will contribute to the improvement of the quality of design and construction products. The quality of the design and construction products can be improved by the development of simulations for an enlargement of the solution space, effective integration, product modelling, and automation (Figure 4).
Information technology will be able to support the integration of information, and the simulation of design and construction aspects. The building industry will have to define the product models with objects, attributes, operations, relations and messages for this integration and these simulations. More and more clients wish to examine the final design or construction product, in a real or simulated form, as early as possible in the process. They also want to know about the performance and consequences (cost and time) as soon as possible. Simulation technologies like presentation media and Virtual Reality will be applied more and more.

The application of quality assurance and a performance concept, with a quality system and formalised procedures, will be an important topic in design firms. There is a change from a capacity-oriented market to a product-oriented market with integral process management in construction firms.

### 4.1.2 Productivity of design and construction processes

Information technology already replaced design instruments and it contributed to the improvement of the productivity of design and construction processes. It will now also replace construction instruments and it will contribute to the automation of design and construction processes. The productivity of the design and construction processes can be improved by the development of procedures for shortening the search path, efficient communication, process modelling, and automation. Information technology will be able to support the communication of information and the procedures for design and construction processes. The building industry will have to define the process models with activities, output, control, input and mechanisms for this communication and these procedures.

Within the context of this theme-report the emphasis is on expectations concerning this building process organisation and more in particular on participants, information, instruments, and co-operation. Offices of building process participants can be decentralised throughout the country, the continent or the world. Employers can work in office hotels. Tele-communication and remote control systems can give the designers and constructors the opportunity to stay up to date and to control design and construction processes. The number of participants will grow due to specialisation. The number of participants answerable to the client decreases through co-operation/co-ordination. There will be a more or less consistent relationship between client, process manager and/or architect.

The need for a more client and customer-oriented building process is becoming an important driving force for organisational innovation in the building industry. The design brief may change from a unique document to an evolving document.

Because of the integration of design and construction information, engineering offices will integrate as well. Designers and engineers responsibilities may be limited to making a functional and technical design (design for purpose, design for performance, performance specification). Contractors submit tenders based upon their own technological design (design for production).

There will be a move of construction and/or production activities from the building site to the industry, with an emphasis on logistical aspects and assembly of products. There is a trend towards organising the process, based on the principle of system (unit) contracting. The basis of this is breaking down the design and construction part of the process into units that are technical and logistical independent and that can be contracted out separately. System unit contracting puts a strong pressure on standardising joint details. On the other hand it gives far more freedom for innovation within a system unit. Building information technology specialist will play a central role in the joint efforts, with the building industry and information technology, for the development of information technology in the building industry. Together they will build and established operational models of the building industry prior to introduction or implementation of information technology.

The building process will develop from unique and project dependant to standard and product dependant. The organisation will develop from project oriented with incidental co-operation to product oriented with structural co-operation.

In certain segments of the market specially the large building firms offer total service packages in which constructing a building is just a part and in which also are included components like financial engineering, development and design and facility management. The building process becomes here an in company production process in stead of a process of different co-operating firms. Building companies will have to make a strategic choice in what segment they want to be active. Building process management should follow this segmentation and adjust its performance to the requirements of projects in specific segments.
4.1.3 Integration

Effective integration of information in systems in organisation is essential to a controllable information system, and should in the long run contribute to an information implosion. Innovative integrated firms, or groups of co-operating firms, take the lead in this area and a distinction will grow with more traditional projects and firms. Information technology is seen as a critical factor for competition.

Product modelling is important for a sound foundation for a Computer Integrated Construction (CIC) framework. Building product models may become the bases for inter-professional integration and communication. These models should improve the use of integrated information technology in the building process where possible.

Information is an important element of building process organisation. It flows through the whole building process and between all the different participants. Usually information is duplicated and held and used in different formats by various parties. A lot of failings are related to inadequacies in information. Integrated information technology will really improve the building process organisation. Compatibility of systems would allow a direct transfer of information to all parties involved.

4.1.4 Communication

Efficient communication of information in systems in organisation is essential to a controllable information system, and should in the long run contribute to an information implosion.

Communication techniques will reduce the mobility of people, traffic, and transportation.

Applications of information technology will make use of local and distributed computer systems and (tele)communication techniques and media.

On the medium term one may expect more or less closed networks of co-operating EDI users to appear in the building industry. On longer term EDI will become a more normal tool for data interchange, at least for the medium size and larger firms. EDI will strengthen the explicit distinction between innovative and traditional firms.

The core of information technology applications in the building process is the project data base, in which all project related data is stored and through which process participants communicate and exchange information. Standards for communication and information transfer must be agreed upon between the participants involved. Some of these standards will be project dependent, some of them will have a more general nature. The ability to participate in this type of communication is a key factor in the selection of partners per project. The needed investment involved this technology may become a strong driving force towards project independent partnership or firms co-operating in projects.

4.2 Potential consequences for the future building process organisation

In the building industry there are three main streams with idea's about the implementation of information technology:

- information technology is necessary for adjustments of the building industry;
- information technology can only play a part in the building industry after a change has been made from construction to industrialisation;
- no changes, gradual integration, changing the market, changing the process, (partly parallel, partly sequential).

4.2.1 Advantages

The speed of information technology implementation in the building industry will be different per market segment. It will depend on the expected added value of information technology applications related to the type of projects (capacity oriented, product oriented etc.). Information technology may become a crucial factor in the development towards a more explicit segmentation of the building market and the building industry.

For small and capacity oriented building companies working in the local market on small projects on behalf of non-professional clients, the benefits and application of integrated information technology systems will be far less than for large building companies working in the international market on complex projects with many partners on behalf of professional clients. Especially those companies that are able to deal with an industrial approach to the building industry will be able to gain advantage from information technology (Figure 2).

Information technology is the most general technology that has ever been available for the building industry. The proper use of information technology will be indispensable for an efficient, quality oriented and integrated building process.
4.2.2 Influences

The building industry and the information technology need to develop their own scenario's and strategies. Together they have to agree upon feasible goals, relevant problem statements, and useful system specifications.

Research and development will be carried out as a joint effort of the building industry, information technology, and specialists in building information technology. A design and construction language, with syntax, semantics and pragmatics, will be developed for the description of design and construction products, processes, and organisations. This language will also be used for the description of simulations and procedures.

Research on information technology in the building industry should be directed towards agreements on the integration of design or construction aspects and on the communication of design and construction information.

The influence of information technology depends on project and product type, and on the complexity of the project and the organisation (Figure 2). However, the application of information technology should be stimulated during design and construction processes. Information technology should be developed to replace traditional information media to allow for a paperless building process.

Some participants in the building process will be educated as building information managers and/or technicians. Building information technicians are those capable of tuning information technology to the building industry. A background from the building industry is of assistance in understanding this need. A building information technician should also be able to control the implementation of information systems.

There is a continuance need for international monitoring of developments.
Figure 1: Trends and developments; Potential consequences
This figure represents trends and developments for the implementation of information technology in the building industry. It shows potential consequences for a future organisation of the building process. It is based upon a distant view on the building process organisation and on a closer view on the information technology.
Figure 2: Motivation for change

The possibilities to use information technology have increased. Still information technology hasn't been able to contribute to the building industry, or, even better, the building industry hasn't been able to gain advantage from information technology. Obviously there is a lack of influence in both ways. The building industry and the information technology need to develop their own scenario's and strategies.

The question related to the building process organisation is: "How can the building industry gain advantage from information technology?"

The question related to the implementation of information technology is: "How will the building industry be influenced (changed) by information technology?"

For small and capacity oriented building companies working in the local market on small projects on behalf of non-professional clients, the benefits and application of integrated information technology systems will be far less than for large building companies working in the international market on complex projects with many partners on behalf of professional clients. Especially those companies that are able to deal with an industrial approach to the building industry will be able to gain advantage from information technology.

The influence of information technology depends on project and product type, and on the complexity of the project and the organisation. However, the application of information technology should be stimulated during design and construction processes. Information technology should be developed to replace traditional information media to allow for a paperless building process.
Figure 3: Need for feasible goals
The building industry and the information technology have to agree upon feasible goals. To support the objectives of the building industry, information technology should contribute to the improvement of the quality of the design and construction product, and the productivity of the design and construction processes.

The questions related to the possibilities of information technology in the building industry are: "How can information technology contribute to the improvement of the quality of design and construction products?" and "How can information technology contribute to the improvement of the productivity of design and construction processes?"
Figure 4: Need for relevant problem statements
The building industry and the information technology have to agree upon relevant problem statements. The quality of the design and construction product can be improved by the development of simulations for an enlargement of solution space, effective integration, product modelling, and automation. Information technology will be able to support the integration of information, and the simulation for design and construction processes. The building industry will have to define the product models with objects, attributes, operations, relations and messages for this integration and these simulations.

The productivity of the design and construction processes can be improved by the development of procedures for shortening the search path, efficient communication, process modelling, and automation. Information technology will be able to support the communication of information and the procedures for design and construction processes. The building industry will have to define the process models with activities, output, control, input and mechanisms for this communication and these procedures.

The question related to the limitations of information technology: "How can an effective integration and efficient communication be established?" or "How can an information explosion be prevented?"
Figure 5: Need for usefull specifications

The building industry and the information technology have to agree upon useful system specifications. Insight is necessary in the organisation of the building process for a design of information systems and for a qualitative implementation of information technology. The use of information technology, in relation with the building process organisation, should be aimed at an improvement of the quality of the building product. Therefor information technology should support simulations of design and construction aspects, integration of information, product modelling and automation in design and construction information systems. This support is dependent of the advantage the building industry is able to gain from information technology. It is limited by the confusion that exists in the building industry and the scarce research and development and education and training efforts and facilities.

For the realisation of information systems and for a productive implementation of information technology in the building process organisation, insight is necessary in information techniques. The use of information techniques should be aimed at an improvement of the productivity of the building process. Therefor information technology should support procedures for design and construction processes, communication of information, process modelling and automation of design and construction processes. This support is dependant of the influence of information technology on the building industry. It is limited by the complexity of the building industry and the existing application and management environment.
Figure 6: Insight in process and organisation of the building industry
In this figure the emphasis is on relevant building process participants, design, construction and management information, information technology as instrument, and on cooperation between the participants, using this technology.
Figure 7: Insight in information techniques of the information technology
Examples of applications in the building industry show the use of local computer systems, and hesitation in the use of distributed computer systems, (tele)communication techniques and other media. Applications of information technology will make use of local and distributed computer systems and (tele)communication techniques and media.
Insight is required into the development of information techniques in general and more specifically in the building industry. Research and development, education and training, application and management should be carried out as a joint effort of the building industry, information technology, and specialists in building information technology.

The advantage the building industry is able to gain from information technology is limited by the confusion that exists in the building industry and the scarce research and development and education and training efforts and facilities.

The influence of information technology on the building industry is limited by the complexity of the building industry and the existing application and management environment.

Figure 8: Joint effort of building industry, information technology and building information technologies
Figure 9: A language for the description of products, processes and organisation
Research and development will be carried out as a joint effort of the building industry, information technology, and specialists in building information technology. A design and construction language, with syntax, semantics and pragmatics, will be developed for the description of design and construction products, processes, and organisations. This language will also be used for the description of simulations and procedures.