Future organisation of the building process

Smeltzer, G.T.A.

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FUTURE ORGANISATION OF THE BUILDING PROCESS
INFORMATION TECHNOLOGY IN THE BUILDING INDUSTRY

Geert T.A. Smeltzer

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Future Organisation of the Building Process: Information Technology in the Building Industry

Geert T.A. Smeltzer

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Introduction

This chapter "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 chapter 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 a theme report on this subject that was based upon (inter)national inventories, brain-storm reports and some other papers. This chapter should contribute to a synthesis of trends and developments in four different area’s. These area’s are the building market, information technology, global mega trends and management philosophy. This synthesis will eventually lead to the scenarios for a future building process organisation.

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 chapter 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 chapter "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

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 scenario's 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.

1.1 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.
1.2 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).

1.3 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 inter-
professional 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 therefor 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.
2 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.

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.

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.

2.1 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.

### 2.2 CAD/CAM

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. 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.

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

2.3 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. 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. 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.

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; EDI focus's on electronic communication between computer systems that support business transactions. The digital data that is exchanged is called an EDI message;
- PDI: Product Data Interchange; PDI focus's primarily on electronic communication of PDI documents or PDI models between computers that support technical processes; PDI-document (data based on files); Typical PDI-files are technical drawings and technical product information; PDI-model (data based on models); 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. 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.
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.

**EDI/PDI developments**
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.

2.4 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 external 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.

2.5 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.

**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.

**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)

**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;
- 3 dimensional model;
- simulation of attributes;
- generated representation
- minimal reproduction in mono (as appropriate also in stereo).

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).

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.
3 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)

3.1 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 on 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 on 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.

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.

**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.

**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.

**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.

3.2 Potential consequences for the future building process organisation

In the building industry there are three main streams with ideas 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).

**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.

**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
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.
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?"
Advantages

Influences

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?"
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 co-operation 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.