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Human-Machine Technologies for Construction Sites

Frans van Gassel - Ger Maas

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Preface

We dedicated the topic of 'IT Communication Technologies on Construction Sites' to the meeting of the Task Group TG27 in Munich on 2 April 1998. One of the technologies applied on construction sites is telecommunications. Telecommunications tools for the construction site are the latest in the long line of automation instruments that has penetrated construction companies and consultancies during the past twenty years.
Automation started with salary administration, followed by word processing for the secretariat and PCs for calculations in the drawing office: today, a planning and control office without a calculation, planning and drawing package is unthinkable. For large projects or projects involving working with partners over large distances (foreign architects) we can no longer do without electronic data exchange during the preparatory phase of the construction process.
The question now facing us is, how can data be exchanged electronically with the construction site (management, personnel and equipment).

The Advisory Council on Technology Policy for the Construction Industry (ARTB) in the Netherlands submitted its *Bouwvisie 2015* (Construction Vision for 2015) in January 1998. This report makes a number of suggestions for the development of the technology needed in the future.

The chapter entitled '*Technologie en arbeid in de bouw*' (Technology and work in the construction sector) contains the following statement in the paragraph '*Uitvoeringstechniek*' (Construction Engineering and Management):
"In 2015, the organisation of construction work on the construction site will have learned a great deal from modern industrial planning methods, in which the greatly improved communication between work preparation and realisation will be particularly striking.
Many construction sites will have extremely good links with the planning departments and the permanent evaluation of the progress of construction projects will have borne fruit in many companies. 'Zero construction errors upon delivery' will be the rule".

At the meeting, Frank Schulze of Hochtief gave some details of the Mobile Integrated Communication in Construction (MICC) project and The Eindhoven University of Technology gave a presentation of developments in the area of telecommunications tools that were on display at the BAUMA98.

In view of the level of attention at the meeting, it appears that there is great interest in this subject.

The TG27 and members' research projects were also discussed at the meeting.

These proceedings give a report and further elaboration of this meeting.

Eindhoven, December 1998
Ger Maas,
TG 27 Co-ordinator.

Contents

1. Meeting in Munich

On Thursday, 2 April 1998, the CIB TG27 held its second meeting in Munich.
The participants at this meeting were:
Prof. Ir. Ger Maas, Eindhoven University of Technology, The Netherlands, Co-ordinator
Ir. Frans van Gassel, Eindhoven University of Technology, The Netherlands, Secretary
Prof. Dr.-Ing./Univ. Tokyo Thomas Bock, Munich University of Technology, Germany,
Ms. Edeltraud Döllerer, Munich University of Technology, Germany,
Hannu Koski, MScTech, VTT, Finland,
Dr. Yehiel Rosenfeld, Technician - Israel Institute of Technology,
Univ.-Prof. Dr.-Ing. Rainer Schach, Dresden University of Technology, Germany,
Ir. Frits Scheublin, HBG, The Netherlands,
Prof. Miroslaw Skibniewski, Perdue University, USA,
Dr. Robert Wing, Imperial College London, United Kingdom,
Theo van Rijn, M.Sc.Eng.CPIM, Netherlands Organization for Applied Scientific Research (TNO),
Dr. Steven Lorenc, North Carolina State University, USA,
David Cobb, BSc(hons) Msc MBA Ceng MICE, Herts, United Kingdom,
Dipl.-Ing Mike Gralla, Dortmund University, Germany,
Dipl.-Ing Michael Jablonski, Dortmund University, Germany,
Dipl.-Ing Frank Schulze, Hochtief IKS, Frankfurt am Main, Germany,
Dr. Ir. Wim Schaefer, Eindhoven University of Technology, The Netherlands,
Arko Heitbrink, Eindhoven University of Technology, The Netherlands,
Moniek Stoffele, Eindhoven University of Technology, The Netherlands.

The programme of the CIB TG27 meeting was based on the theme:
'IT Communication Technologies on Construction Sites'.

Some of the participant on the meeting in Munich. From left to right: Ger Maas, Hannu Koski, Frans van Gassel, Thomas Bock, Arko Heitbrink, Edeltraud Döllerer, Yehiel Rosenfeld and Theo van Rijn.

The following points were on the agenda.

- Thomas Bock described his research projects in Karlsruhe and the coming projects in Munich. See Appendix A.
- Frank Schulze from HOCHTIEF presented the MICC project in which his company is participating.
- Ger Maas gave an overview of examples at the BAUMA related to the theme of the meeting.
- Arko Heitbrink informed us about the results of the 'International Status Report' study.
- Frans van Gassel presented a structure with which to present the research projects of the members on the Internet.
- The last activity was a discussion in two groups about the kind of research that the participants/members would like to accomplish.

These proceedings represent a report on and elaboration of the meeting. The first part of the proceedings discusses subjects related to the theme of 'IT Communication Technologies on Construction Sites' and the second part contains the results of the 'International Status Report' research project and of the discussion on research themes by the TG27 members.

2. IT Communication Technologies on Construction Sites

Communication is required in order to allow people and machines to perform tasks on the construction site correctly, day after day. In addition, the operational management is to be able to communicate quickly with the construction site whenever factors that disturb the planning are present: bad weather, mechanical failure, traffic congestion, employee absence, inadequate work instructions and unforeseen combinations of circumstances.

The quality and quantity of the information exchange has a partial influence on the construction cost, completion time and quality of the result.

The use of information technology offers opportunities to allow optimum communication to take place. In order to achieve this, the following questions can be put:

- What information does a construction site employee or machine need in order to perform a particular task?
- What information arises at the construction site and with which people or machines is this information exchanged?
- What (mobile) means of communication for data exchange and voice transmission are suitable for the construction site employee?
- How quickly does data have to be exchanged?
- What are the consequences of the use of communication tools for the layout of the workplace and site office?
- How does communication with the construction site surroundings take place: operational management, work preparation, suppliers, consultants and principals?
- Is communication through tools sufficient, or is personal communication still required?

This reader will attempt to deal with some aspects of these questions.

3. Aspects of Electronic Communication

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3.1 What is communication?

A great deal has been written about communication. In 1977, K. Merten had already collected 160 different definitions. In relation to some elements, academics often do not agree with one another on what is and what is not meant. What is generally accepted, however, is that communication can be regarded as the exchange of information.
In order to gain insight into the phenomenon of communication, an elementary communication model is often used. Although initially devised to describe verbal communication between several people, this model is also perfectly suited to further describe man-machine and machine-machine communication. According to this model, communication in its most basic form consists of a sender, a message, a channel and a receiver.

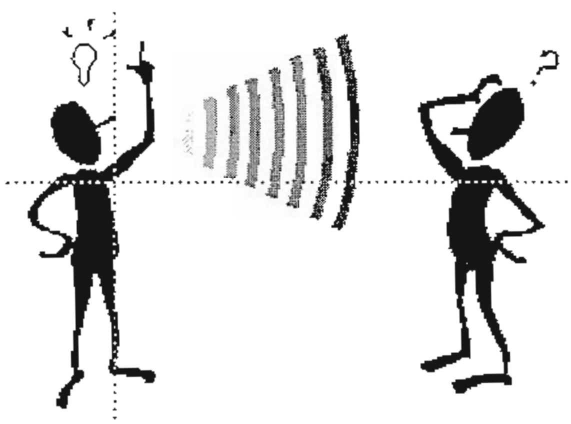


Figure 3.1. Communication model.

The sender must first give shape to his thought. To encode it in jargon. The encoded idea must be coded. In other words, words are transformed into signals, such as signs or spoken words, which are then transmitted through a line of communication. The receiver must then in turn decode the coded message, decipher it and then interpret it (Figure 3.1)..

During all of these stages, errors are possible, both in terms of content and technology. Examples of the latter include an empty battery in a GSM mobile phone or a computer link being 'down'.
In terms of content, there are three aspects that can go wrong. The communication may be disturbed by too much background noise. Background noise is the addition of information that is not relevant. For example, a meeting at which everyone is talking at the same time or a telephone conversation on a construction site where the first pile is being driven.
It can also go wrong if the sender's and receiver's interpretations of the information are different: the sender and receiver are using the same term, but each attaches a different meaning to it. One of the greatest problems in the construction sector is to determine a clear frame of reference in which no confusion is possible. A great deal of research is being performed into this aspect within the framework of product and building models. In the Netherlands, the Building Agreements System organisation (BAS) is one of the bodies looking into this subject.
Lastly, the communication may lose quality if the language, including the set of definitions and possible sentence structures, is too limited. For instance, the hypothetical case that the word 'television' does not exist in our language, but you want to buy such a machine. You will have to

find a description, and run the risk that it is not complete and can lead to misunderstandings or a total lack of understanding. The same problem occurs if the receiver's vocabulary is too limited, in which case further training is an adequate remedy.

3.2 Why communication?

Communication does not take place without an objective. With his message, the sender attempts to influence the behaviour, views or ideas of the receiver. The extent to which this succeeds is known as the communication effect. The effect depends strongly on the form taken by the communication. Argelo and Boterman distinguish between three forms of communication. The first category is free communication, confined at most by a social code of behaviour, but not subject to further formal rules. A sentence such as "Now I've run into you, how is the project coming along?" falls into this category. The second category is communication bound to formal rules. For example: "Every month, a written progress report will be sent to the planning and control office". And the last category concerns communication through designed data streams. EDI and PDI are examples of such communication. It should be clear that the communication effect in the last two categories should be immediately and 100% complete. If not, there are in all probability errors in the formal description of the data or exchange protocols. By 'immediately', we are referring to the absence of a conversation such as takes place in free communication. During such a conversation, misunderstandings or unclear elements are detected and corrected by the partners in the two way-conversation. EDI-oriented or PDI-oriented communication does not support this kind of correction mechanisme.

Philosopher, physician and psychiatrist K. Jaspers (1883-1969) made another distinction between types of communication. He defined four types: vital communication, intellectual communication, spiritual communication and existential communication. The strength of this division is that it corresponds well to everyday experience.
We speak of vital communication when people understand one another without exchanging many words. An example is an experienced team that almost instinctively understand one another. Vital communication has an intuitive character, in which posture and gestures play an important role. Intellectual communication concerns rational, businesslike and objective communication as used in science and commercial transactions. In the case of spiritual communication, people do not think and speak in a purely businesslike or objective manner. Common standards, shared values and ideals play an important part in this. In existential communication, each individual is personally at issue. This communication conveys something about the unique nature of the other. It is the most spontaneous method of communicating and depends on the moment of the day.

This classification of types of communication has been included here to point out that people use a mixture of all of these communicationtypes in their daily business. Digital communication on the other hand only support a formal approach. So, what it boils down to is that digital communication represents an enormously reduction compared with human communication. This need not be a bad thing, as long as we are aware of this.
A good example is the study recently carried out by a student at the faculty of Architecture at the Eindhoven University of Technology. She studied the possibility of making product data from suppliers available to product developers through the internet. The advantages were obvious, namely up-to-date information that was quickly and simply accessible. From a number of interviews with product suppliers, it appeared however that the suppliers were by no means queuing up to provide such a service. They were afraid that this would reduce personal contact. The suppliers saw the advantages, but considered the importance of personal communication to be much greater.

3.3 Impact of information and communication technology

As innovations in technology follow one another at an ever-increasing pace, it becomes increasingly difficult to determine whether something is a hype or a development which should be quickly taken up in order not to endanger the longer-term competitive position.
The opportunities offered by innovations in Information Technology can be indicated quite easily. Suppliers of technological systems ensure that the client is kept abreast of all the possibilities offered by their products. However, a company is not so much interested in the possibilities as in how the technology can be used effectively and efficiently with the company.
An assessment of the impact and strategic significance of the technology to be introduced for the company's operations, personnel and competitive position is also important.

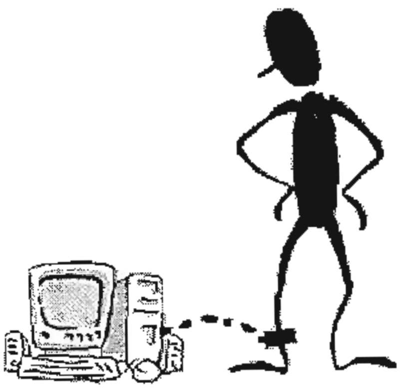


Figure 3.2. Result of bad choice of communications tool.

However, history has demonstrated that determining such impact is no simple matter. Forecasts often more resemble gazing into a crystal ball than a well-founded, considered prognosis (Figure 3.2). Take the invention of the telephone, for example. The speech therapist Alexander Graham Bell had initially further developed the device as an aid for the hard of hearing (both his mother and wife were deaf) and he had no idea of the revolution the telephone would bring about. The same applies to the personal computer, the television and many other inventions.

3.4 Growth model

We can however present a model that shows a line of development for Information and Communication Technology (ICT) related developments as these have taken place on other IT fronts and in other industries. The model indicates the directions of development in the form of scenarios for various growth paths.
Communication is part of a company's information provision. The increasing importance of information provision has made it customary to see this activity as an operational activity, just like purchasing, production and personnel care. The characteristic type of operating asset used by information provision is the information system. And, as with any operating asset, an information system is specified, designed, build, introduced and operated. Three different paths can be taken in this respect. These are reflected in the three growth scenarios in Figure 3.3.

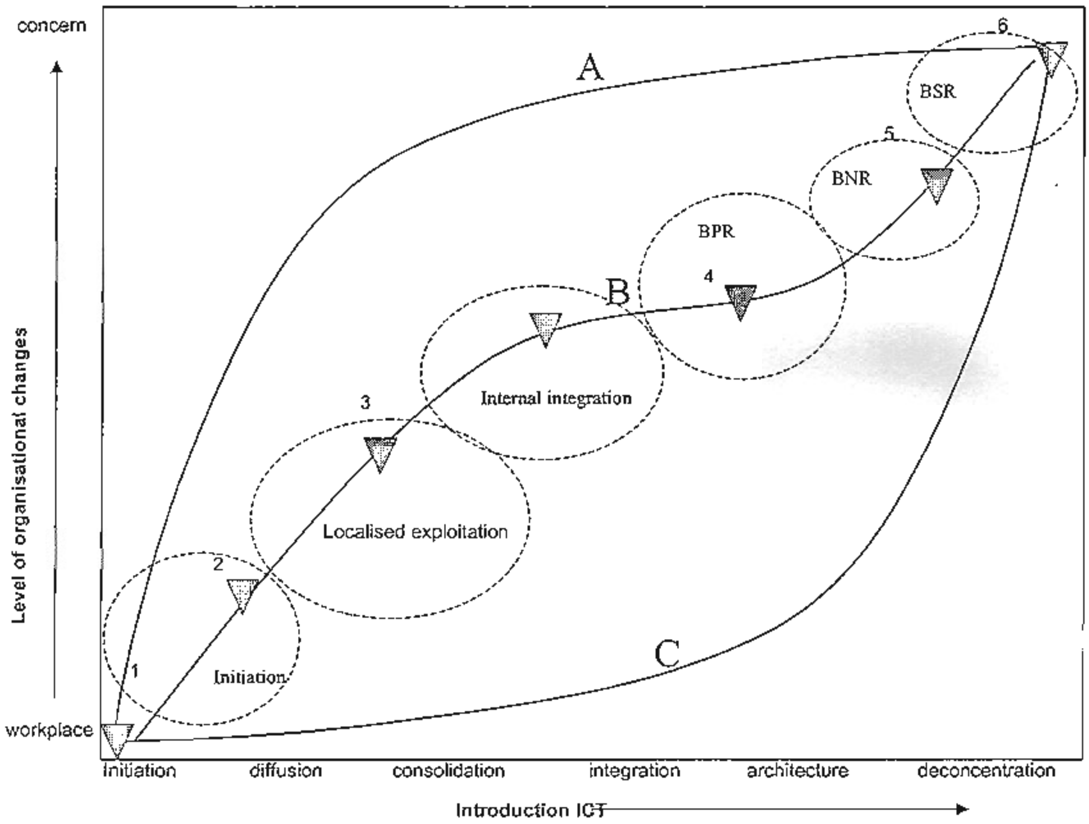


Figure 3.3. Growth stages model.

The phased approach is characteristic of all three scenarios. All stages are passed through one by one. For this reason, we refer to a growth stage model.
The model is derived from the growth stage models of Nolan and Venkatraman. The horizontal axis shows the development van ICT according to Nolan. The vertical axis shows the organisational changes at the various levels, from workplace to concern.

The following stages are distinguished in the model:
1. Initiation
2. Localised exploitation
3. Internal integration
4. Business Process Redesign
5. Business Network Redesign
6. Business Scope Redefinition

During the *Initiation stage*, the initial exploration takes place. For example, by means of the setting up and implementation of a pilot study.

During the *Localised exploitation*, individual operating processes such as a purchase or drawing up a plan are automated. The applications are geared to cutting costs, and do not change the working method.

In the *Internal integration stage*, the integration of several operating processes takes place. We can distinguish two forms of integration, namely technical integration, whereby systems and applications are linked, and the organisational integration of functions and responsibilities.

Business Process Redesign (BPR) involves a radical rearrangement of operating processes, whereby IT acts as an 'enabler'. *Business Network Redesign* (BNR) also concerns a rearrangement of processes, although we are now looking beyond the boundaries of the concern and at the entire logistics chain. The central issue in *Business Scope Redefinition* (BSR) is the possible change or expansion of the scope and mission of the concern.
The first three stages require relatively little change in the existing processes and working methods. Evolutionary growth takes place. This contrasts with the following three stages, in which radical changes take place.

Growth scenario C shows a development path in which the existing processes are first automated as far as possible without making any substantial changes to the underlying business processes. Only once this part is operational and working satisfactorily do we look at optimising the business processes.
Scenario A takes a different route. First of all, the organisation is thoroughly examined and reorganisations are carried out. Once the reorganisation has taken place, the appropriate is considered.
Scenario B describes the traditional approach we are familiar with from Nolan's description where the introduction of ICT and reorganisations go hand in hand. The disadvantage of this approach is that changes take place on two fronts, namely the IT front and the organisational front, and these are constantly interacting with one another. If this process is not carefully planned and implemented, complication can quickly arise and lead to disturbance among both personnel and management and to budget and time schedule overruns.

If we relate the growth model to communications tools and concepts, most developments, such as the fax, telephone and email can be found in the in lower left quadrant. Developments such as on-line access to, for example, implementation plans and PDI are located in the middle of the model. The communication container in the MICC project (Chapter 5) requires far-reaching integration of different logistics processes between the various companies. In the growth model, the communication container can be found in the upper right quadrant.

The same quadrant in which we have placed the communication container also contains the new generation of ERP systems. These systems are not function-oriented or project-oriented, but place the emphasis on business processes and workflow. During the past ten years, the product modelling approach has formed the starting point for the improvement of information exchange between departments and companies. Now it is beginning to look like ERP will become the catalyst. At least, provided that a number of preconditions are fulfilled. One of these preconditions concerns a shift in culture in the construction sector. Lets imagine that a software house wishes to sell a logistics system to a construction company and explains the advantages of the 'Just In Time' concept to the management. The advantages are plain to see: limited stocks on the construction site, reduced losses through damage and theft, better control of the purchasing process. The management is enthusiastic and the system is purchased. Some time later, an evaluation is made. It appears that the system is not functioning satisfactorily as orders are not being delivered according to the planning. What turns out to be the problem? Some suppliers held the point of view that if delivery is scheduled for Monday, delivery on Tuesday morning is also acceptable.
Another precondition lies with the suppliers of ERP systems, such as SAP and Baan. They will have to realise that the large contractors, their best clients in the construction sector, are no longer simply contractors, but have become fully fledged construction companies and are increasingly active in the building design and operation stages. Which means that the functionality of the ERP packages has to increase still further. Once all this has taken place, we may be able to refer in the future to a new impuls to improved communication, namely "ERP-induced Communication".

4. Telecommunications Tools and the Production Process

4.1 The production process
The production process on the construction site transforms materials into a building using people and machines. The construction plan provides information on how this transformation should take place. The production process also creates building waste. Figure 4.1 shows this transformation process in diagram form.

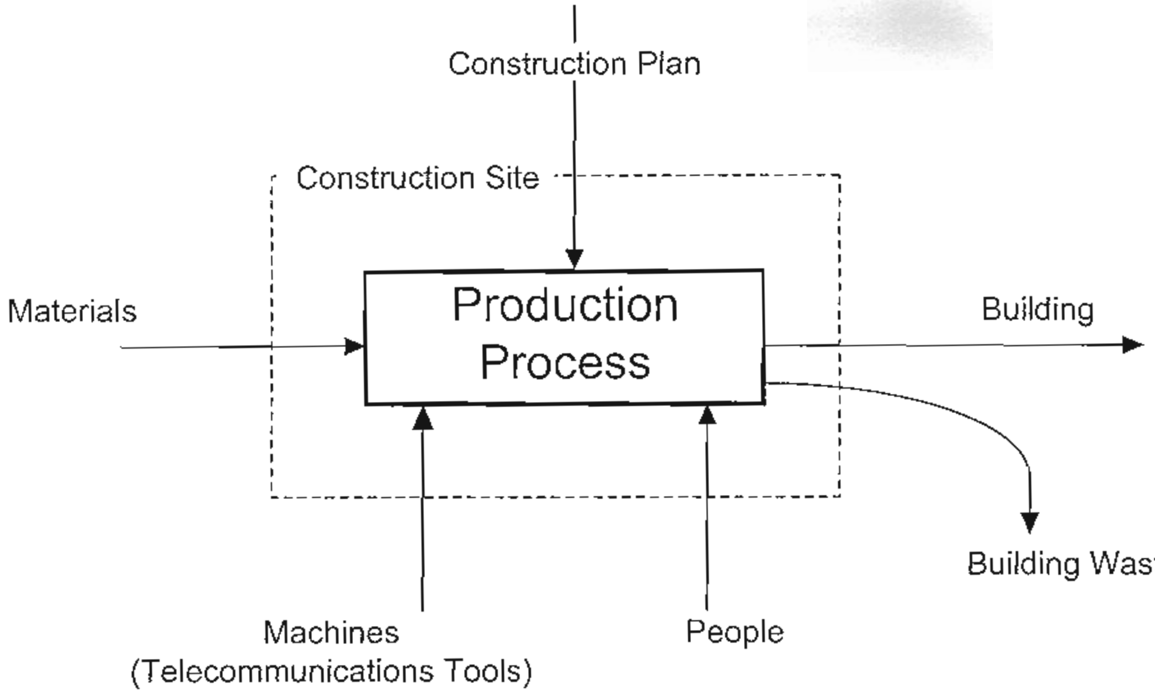


Figure 4.1. Production process on the construction site.

The following paragraphs discuss the specifics of a construction site, the tasks of the people and machines, the construction plan and telecommunications tools.

4.2 Construction site
Production on the construction site has the following characteristics:

- A unique building constructed from many different structural elements.
- A different 'construction sub-process' at a different place every day.
- The construction team is made up of various participants.
- Many specialists are active in the various construction stages.
- The construction site is a temporary production location.
- The participants have their own home bases.
- Short production times are required.

The everyday problems that occur in the management of the production process are in:

- The delivery of materials. When will they arrive, how will they be unloaded, where will they be stored and how many?
- The allocation of people. Which tradesmen do I need, what are their instructions, how do I put a team together and what should I do in bad weather?
- The use of equipment. Do I need two cranes, where are the hoisting facilities, what is the planning?

In order to resolve these everyday problems on the construction site, communication is necessary between the work preparation, construction site management and implementation. The trick is to provide the right people with the right information at the right time. People and telecommunications tools can take care of this.

4.3 Tasks of the people and machines

The production process is performed by people and machines, both of which carry out tasks. The process designer (planner) can choose which tasks will be performed by people and which by machines. People and machines can supply strength and energy, receive and issue information and take decisions.
Both have their limitations in relation to quality and quantity.
Table 4.1 contains an overview of which components of the human body and which machines are used to perform the various functions.

Table 4.1. Various tasks of people and machines. [Van Gassel]

Tasks	People	Machines
Supply strength and energy	Movement system: • muscles • lungs	Power tools: • power sources • transmissions
Receive and issue information	Senses: • eyes • ears • voice • hands	Telecommunications tools: • scanner • microphone • monitor • keyboard
Take decisions	Thought system: • Brain • Memory	Computer equipment: • computer • software • artificial intelligence

4.4 Construction plan

The construction plan contains the information on how construction will take place. Drawing up such plans for production is a design process consisting of the steps: analysis, starting points, concept, design drawing, expansion and detailing. The drafting of an construction plan is a central element between the design of a building and the construction of that building.
The construction plan consists of subplans and scripts..
A subplan describes each aspect of the production process (such as dimensions, time or safety) and gives a specific production aspect for the entire project.
Scripts lay down the production of a specific part of the building and also contain all production aspects.
The two plans can be placed squarely on top of one another. The complete collection of subplans or of scripts both describe the entire construction process. They are two ways of providing the same process information. See figure 4.2. for a diagrammatic representation of the construction plan. [Leijten, Vastert, Maas]

4.5 Telecommunications tools

Telecommunication is communication over great distances using electronic equipment.
Telecommunications tools consist of communications lines and peripherals. A communication line is, for example, a telephone line or a wireless connection with the requisite control equipment.

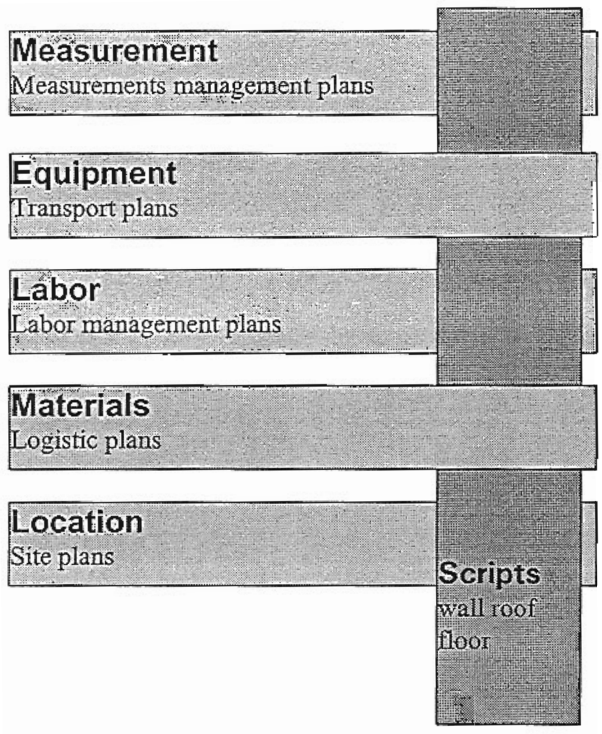


Figure 4.2. Schematic lay out for the construction plan. [Leijten]

Peripherals include a monitor, microphone, keyboard, loudspeaker, etc.
Telecommunication on the construction site may take place between people, machines and databanks. Figure 4.2 shows the possible combinations.

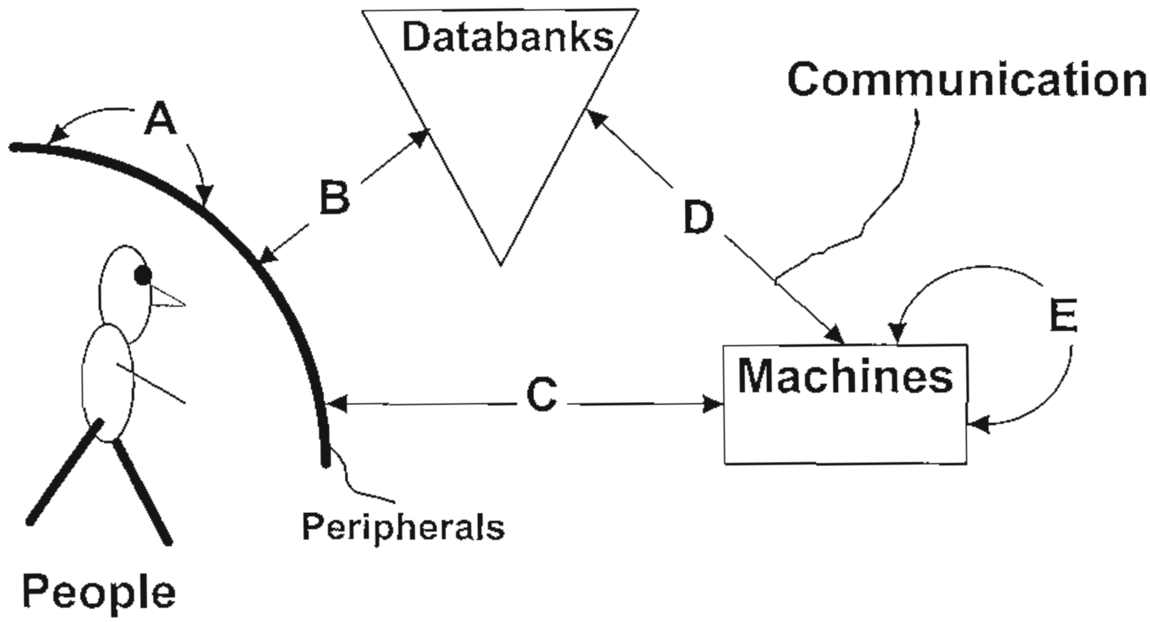


Figure 4.2. *Communication lines and peripherals between people, machines and databanks.*
Line A: between people
Line B: between people and databanks
Line C: between people and machines
Line D: between machines and databanks
Line E: between machines

5. The MICC Project

5.1 Project description

The Mobile Integrated Communication in Construction (MICC) project is a European research project incorporated in the Advanced Communication Technologies and Services (ACTS) programme. The most important partners are the large construction companies from England, France, Spain and Germany. The strategy of the European commission is to reinforce the competitive position of the European construction industry.

The objective is to introduce the use of mobile communication as a means to:

- improve working conditions;
- lower production costs;
- shorten production times, and
- improve the quality of the product.

Mobile communications applications include:

- Collection and electronic storage of construction site data.
- On-line access to, for example, construction plans.
- Operation and monitoring of machinery on the construction site.
- Use of GPS for the construction site lay-out and positioning of structural elements.
- Message and telephone services instead of walkie-talkies.
- Multimedia conferencing.
- Remote inspection, for example using video images or temperature sensors.

5.2 Range of tools

The range of portable and wireless communication tools has increased. Examples include:

- Walkie-talkies.
- Construction-site quality (robust) PCs.
- Power-PC Laptops with video camera.
- Case with integrated PC.
- PC-compatible robust notebook with pen-computing.
- PC-compatible robust hand-held computer with touch screen.
- PC-compatible hand-held computer with integrated Barcode-scanner.
- Printing equipment (laser printers, plotters, etc.).
- Interfaces between PC and wireless networks.
- Telephone systems.
- Mobile telephone.
- Answering machines.

5.3 Laboratory for mobile communication

One of the partners is the *Fraunhofer Institut für Arbeitswirtschaft und Organisation* in Stuttgart, Germany. This institute has a laboratory for research into mobile communications and communications tools. The following work is performed there:

- Testing communications tools, for example for their robustness.
- Integration of communications tools.
- Research into the applicability of tools.
- Design of a communications container.

The research institute also carries out projects such as testing a communications container, measuring climatic conditions and the transfer of video images between a construction site and the contractor's office.
Further information on these projects is available on the Internet at http://www.miks3.iao.fhg.de/micc.

5.4 Communications container

At the heart of the MICC project lies the communications container. The communications container is the site office of the future. This container contains the tools for communication on the construction site and with the outside world by wireless networks.
Communication is possible between builders, teams, foremen, project managers, construction machines, databanks, technical specialists, planners, principals, government officials, etc. Figure 5.1 gives a graphic illustration of the place of this container.

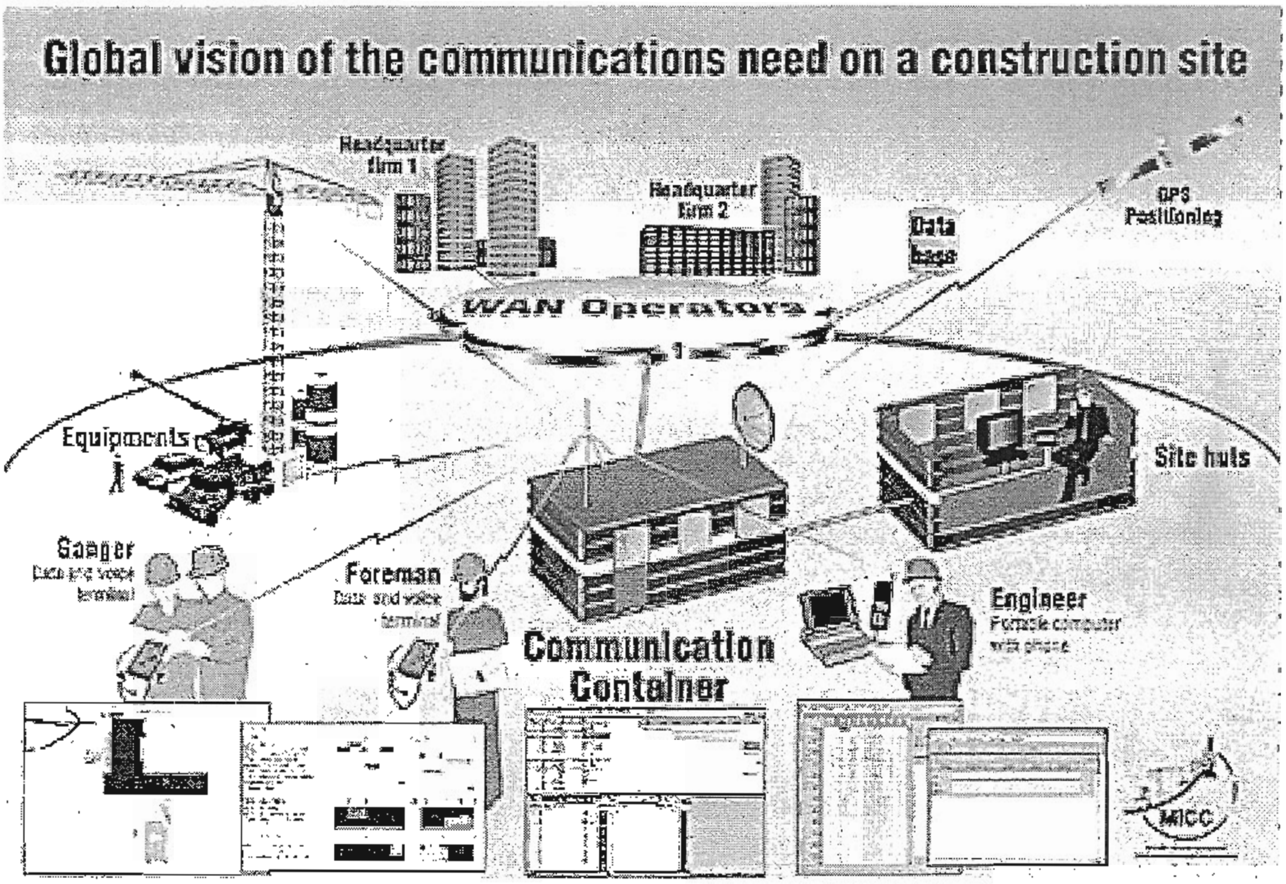


Figure 5.1. The communication container in the MICC-project.

The communications container contains the following components:
- Server power station (back-up, www, printing, emergency power).
- Standard Office software (word processing, spreadsheets).
- Databank (weather conditions, hours, damage reports, etc.).
- Voice communication (mobile telephone, telephone management).
- Data communication (drawings).
- Measuring, control and organisation (climatic conditions, quality of samples).
- Application software with documentation (scanning).

5.5 MICC subprojects

Other projects have also been initiated alongside the communications container, for example:

The shovel loader tracking system

The objective of this subproject is to use GPS satellite positioning technology:
to register the movements and actions of shovel loaders, to be able to work quickly and make the maximum use of machines.
A shovel loader is equipped with various communications tools:
- sensors to register a particular process;
- GPS system to determine the location, and a
- communications unit for wireless transmission of information.

Pile foundation reporting system

The collection of all kinds of data when drilling holes for foundations.
The foreman collects the information in a hand computer during drilling and filling of the hole.
Objective:
- working with a hand computer is quicker than pen and paper, and
- an information database is built up.

The data collection device used is a Psion Workabout.

Concrete delivery system

To replace the registration of concrete deliveries using traditional delivery forms with an electronic data collector.
The form contains information on:
- type of concrete and
- time of preparation.

Advantages:
- no dirty or missing delivery notes;
- entry of authorised delivery notes no longer necessary, and
- quality control linked to the registration system.

5.6 Internet addresses

Information on the MICC project can be found on the following internet addresses:
http://www.de.infowin.org/rus/projects/ac088.htm
http://138.248.65.193/micc/vision.htm.

6. Research Projects

Outside of the MICC project, other research projects are being performed at various locations throughout Europe in the area of mobile communication.

6.1 Construct I.T.

Construct I.T. is a joint operation by a number of English research institutes.

- Management of Communication of Technical Information.
- Towards a Greater Understanding of Communication between Building Designer and Site Worker.
- Exploiting Mobile Computers to Aid Human Memory.
- Simulating Work Process Changes.
- Broadband Integrated Communications in Construction (BRICC).

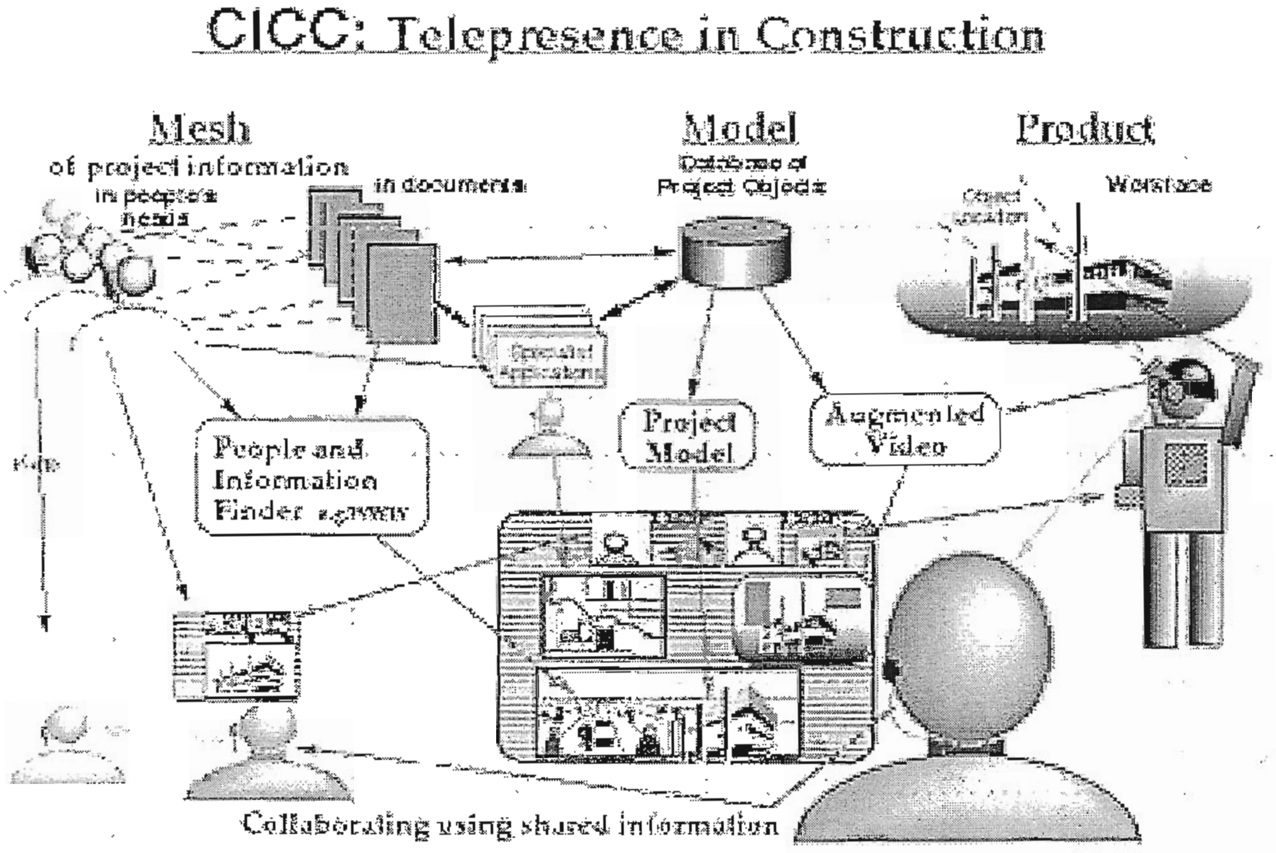
For further information on the Internet, see http://www.construct-it.salford.ac.uk.

6.2 Loughborough University

At Loughborough University in England, the project COMPOSITE, which stands for COmmunication by computer between Main Participating Organisations on SITE, is under way. At present, the research is at stage one: Determination of the critical information flows between the parties on the construction site and outside of the construction site.

6.3 CICC

CICC (Collaborative Integrated Communications for Construction) is an English/Spanish joint operation by companies and research institutes.
It is also a European research project as part of the ACTS programme.



The expected result of CICC is that it will be demonstrated how a number of visualisation techniques can improve the understanding between the partners in a construction project.

Subprojects CICC:
- A People and Information Finder.

A search program for finding people and documents and their relationships.
- Project Model.

Reinforces the connection between client, project team and end-user in order to better understand the characteristics of a specific project.
- Augmented Reality.

Using video and virtual reality, it will be explained what is happening on the construction site in relation to the final product.
- Research into portable computers.

6.4 CSIRO

At the Australian research institute CSIRO, the Global Design Information and Communication in Construction project is currently under way.
Two topics are being examined in this research:
- Integration of design with construction site information
- 'Mobile handheld information' for the architect, consultant and contractor.

6.5 Eindhoven University of Technology

At the Architecture faculty, research projects have been performed during recent years on the subject of communication within the Operational Technology specialist group.
Some of these are:
- Electronic work sheet for the crane operator. (Graduation project)
- Searching for cranes on the Internet. (Graduation project)
- Information provision for an assembly team. (Graduation project)
- Intranet applications for construction projects. (Graduation project)
- A stepping-stone for subplans and scripts. (Graduation project)
- Development of instruments for automated dimensioning on the construction site. (PhD research)
- Research into the use of information technology in the design of the construction process for large-scale residential construction projects. (PhD research)
- Displaying process information using the construction plan. (Education)

7. The Practice[1]

In figure 4.2 are showed five communication lines and peripherals between people, machines, and databanks.

- Line A: between people
- Line B: between people and databanks
- Line C: between people and machines
- Line D: between machines and databanks
- Line E: between machines

In the paragraphs examples are given find in the literature and at the BAUMA98.

7.1 Communication between people

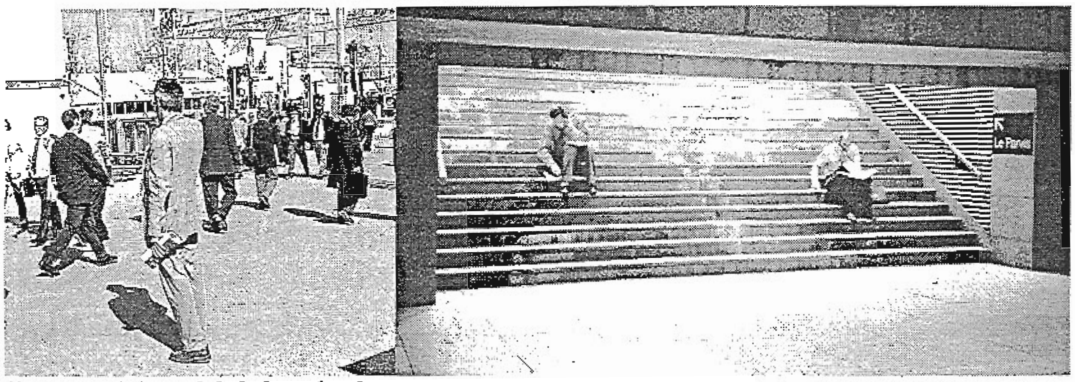


Figure 7.1.1. Mobile telephones

People at the construction site or on their way speak with each other by a mobile telephone.

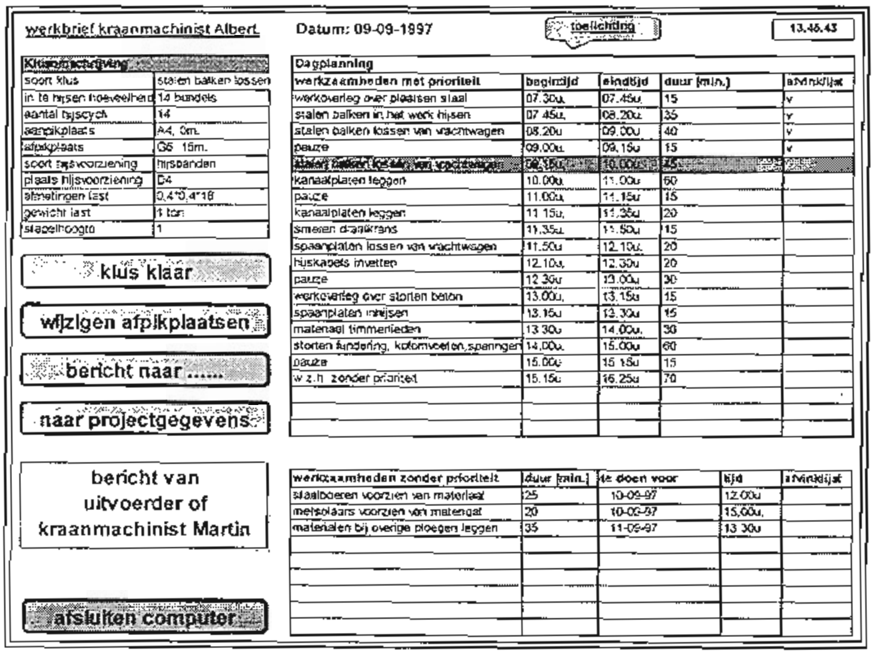


Figure 7.1.2. Communication between site manager and crane driver. (in Dutch)

The crane driver can see on the computer screen in his cabin what kind of hoist activities he had to do on a certain day. The site manager send this information by a communication line to the tower crane. [Van Overveld, Van der Sanden]

[1] Gathered by Ger Maas, Arko Heitbrink, Moniek Stoffele and Frans van Gassel

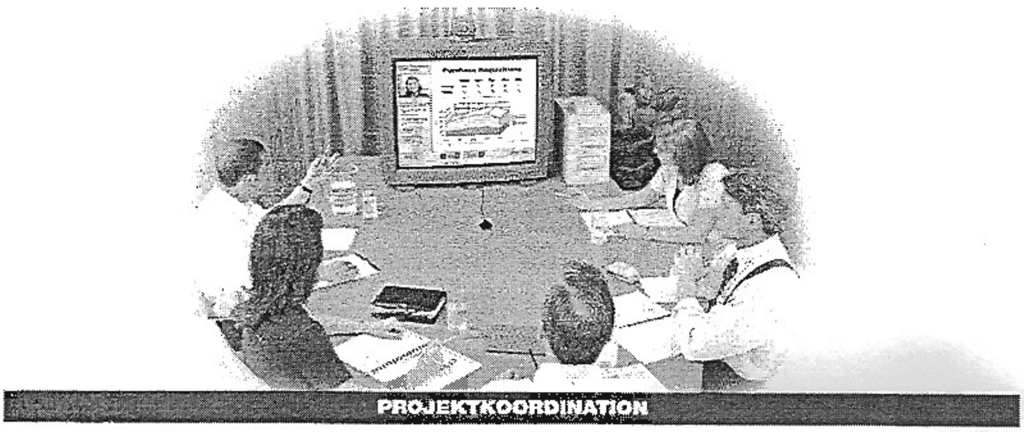


Figure 7.1.3. Information transfer by video-conferencing.
On distance work meetings can be hold.

7.2 Communication between people and databanks

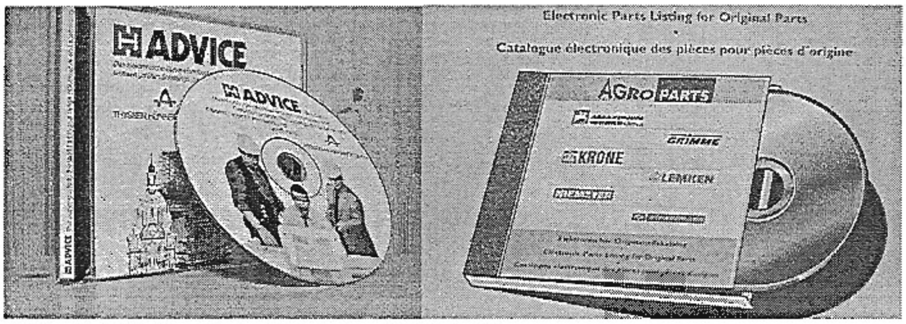


Figure 7.2.1. Searching in databanks
The search of parts and mounting instruction of a form work system.
The search of spare parts for a machine.

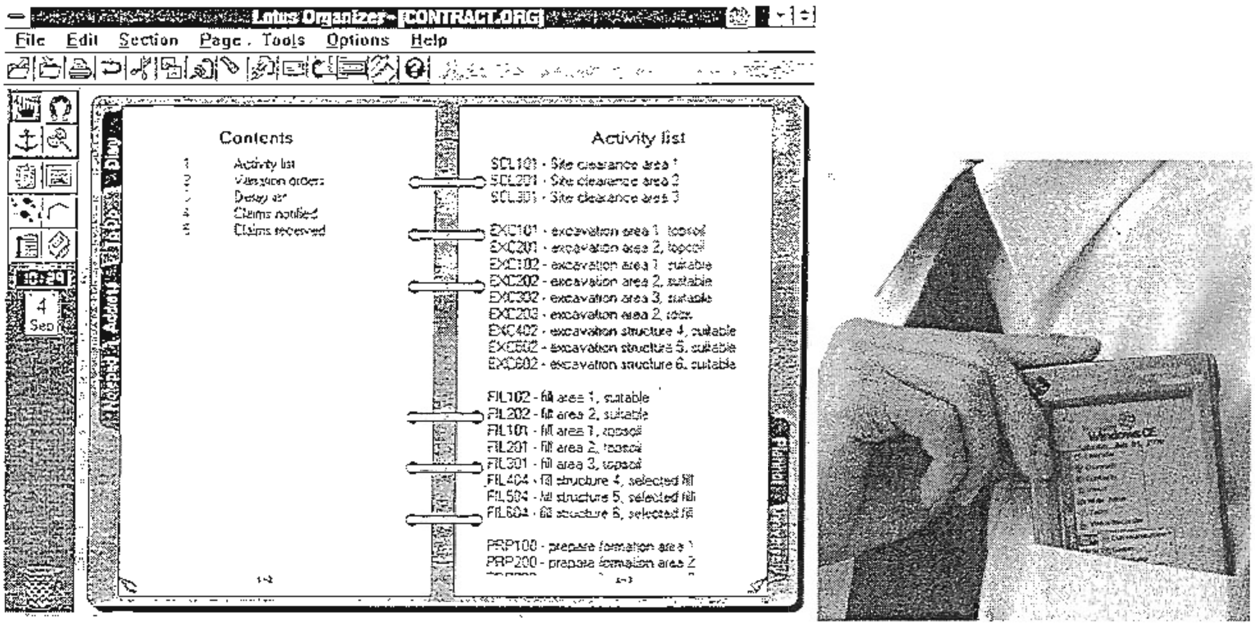


Figure 7.2.2. Storing information in a site diary.
Storing daily information in a Palm PC.

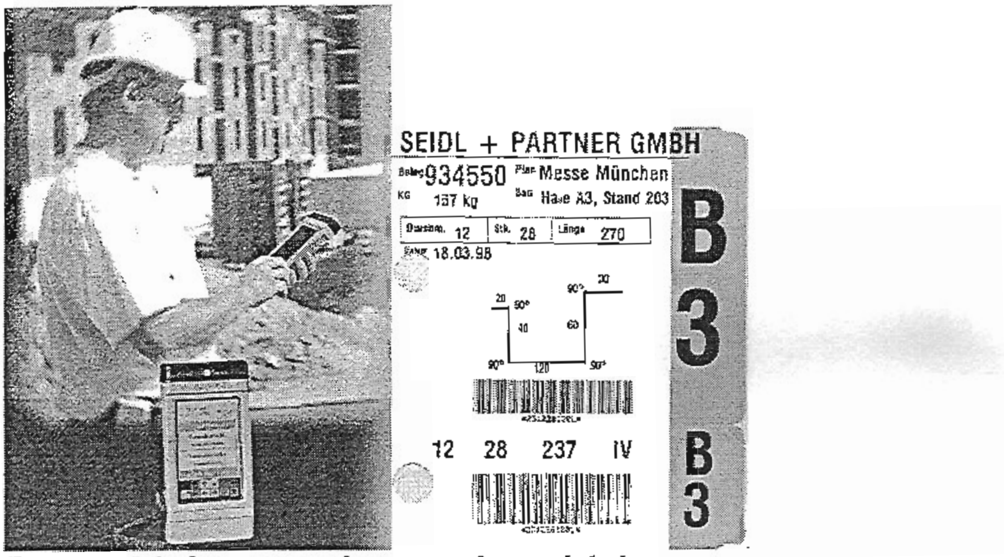


Figure 7.2.3. Scanning information from a label.

Figure 7.2.4. Learning with a CD-ROM as a 'simulator'.
The crane driver can simulate behind his computer special hoist activities for special cranes.

7.3 Communication between people and machines

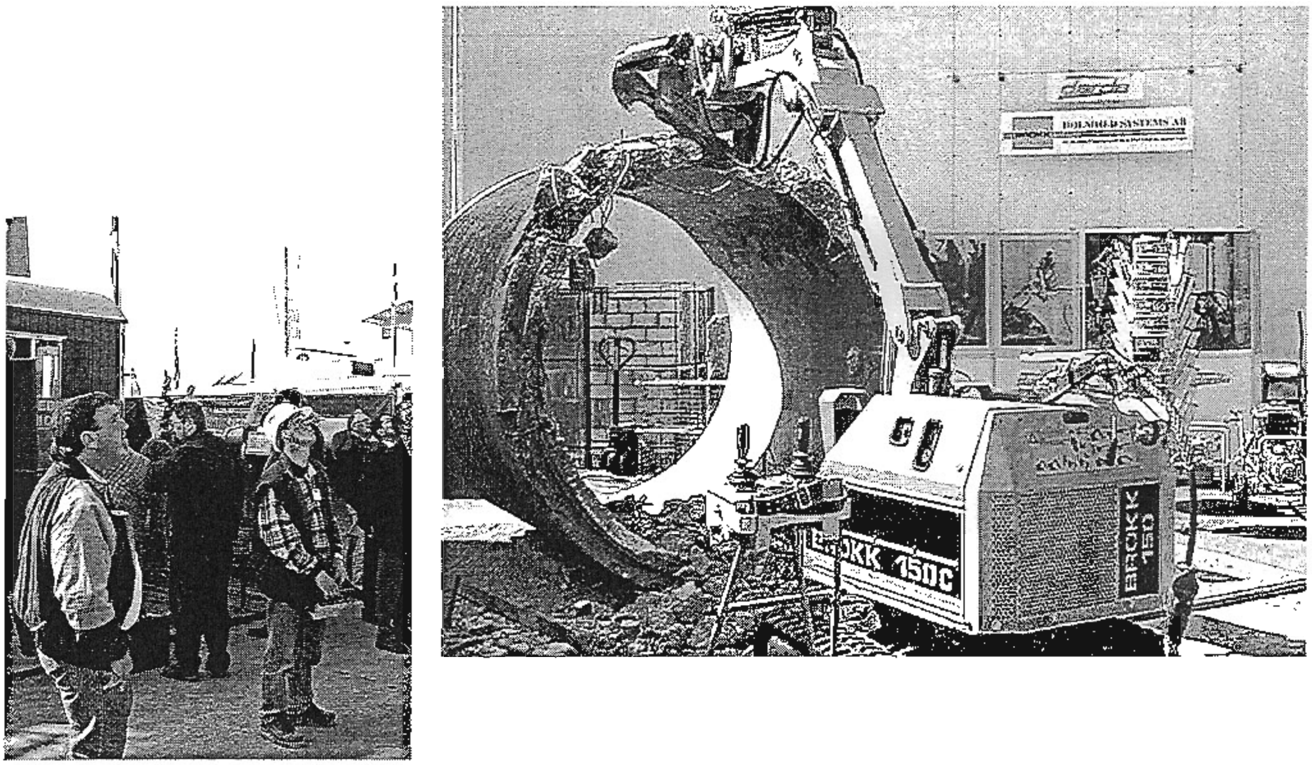


Figure 7.3.1. Operation on distance

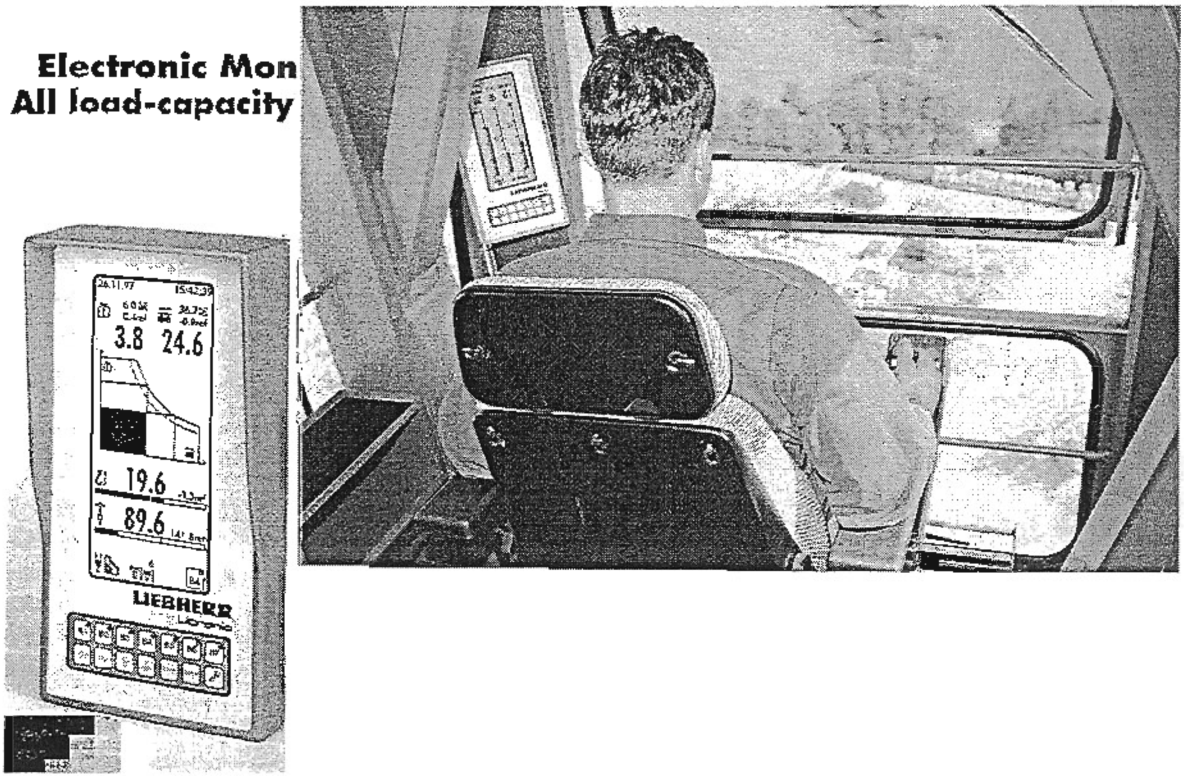


Figure 7.3.2. Displaying performances of machines.

The crane driver can see on a display what performances the crane does. For instance the height and distance of the hoist.

Figure 7.3.3. Registration performances of a machine.

The site manager or an equipment supplier can after a week seen what kind of performances a machine has done.

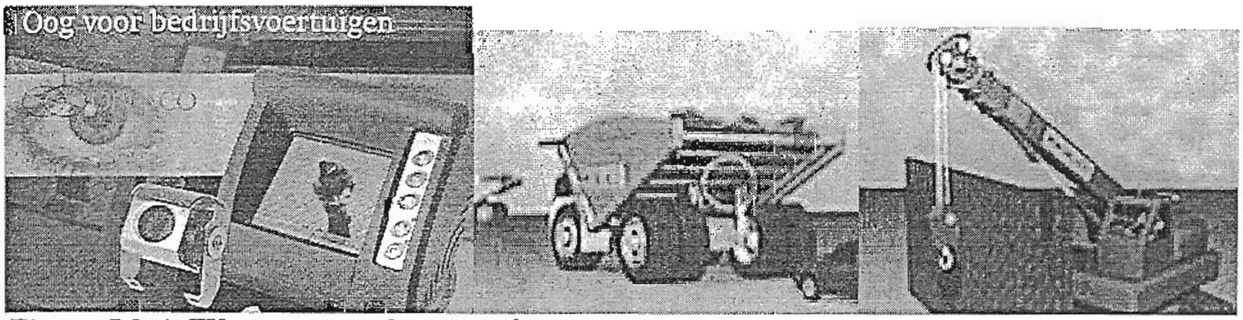


Figure 7.3.4. TV cameras and screens for extra eyes.

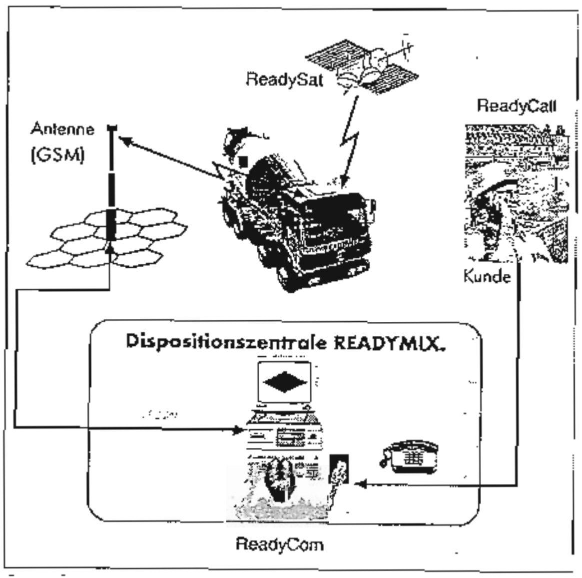


Figure 7.3.5. Information exchanging between material suppliers and their fleet.

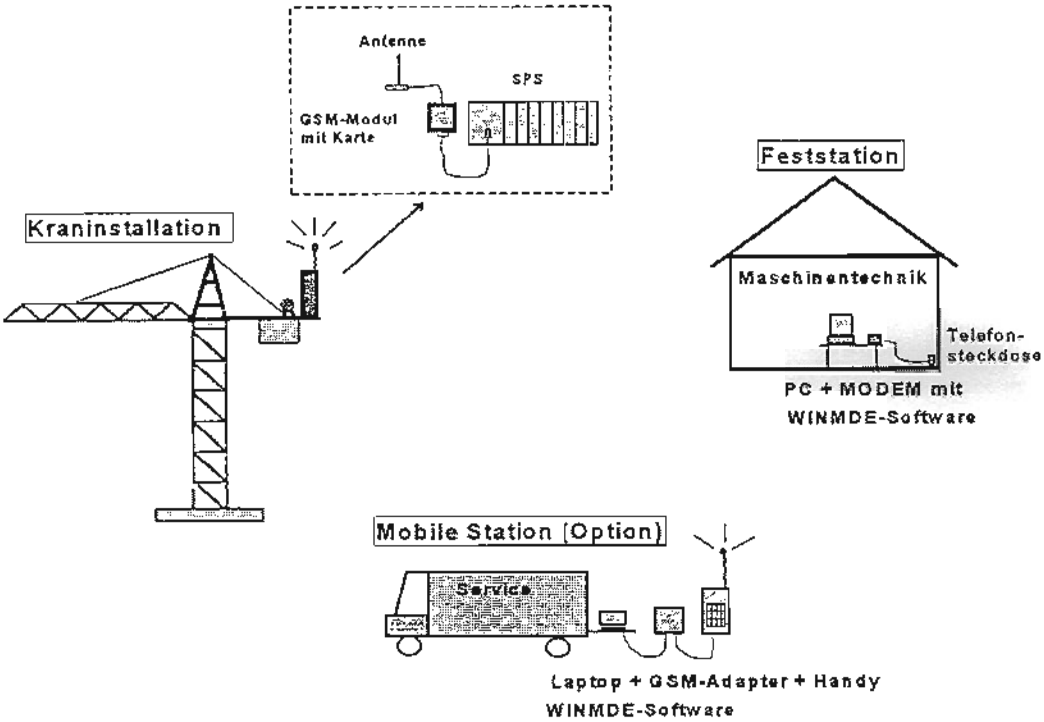


Figure 7.3.6. Information exchanging between equipment suppliers and their equipment.

Figure 7.3.7. Information exchanging between driver and machine.

7.4 Communication between machines and databanks

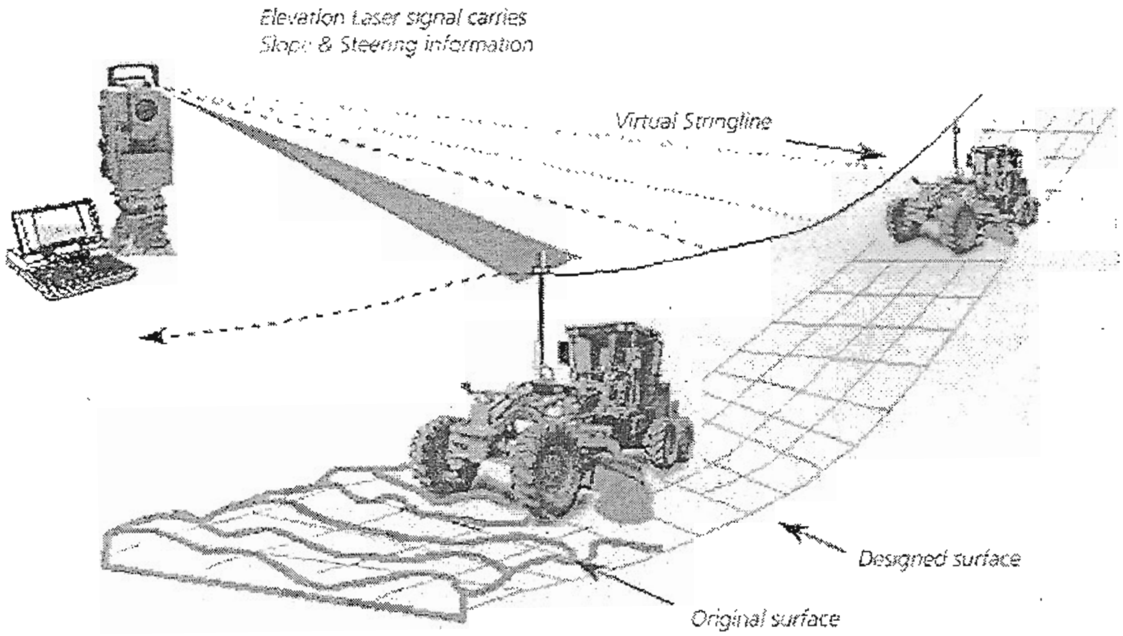


Figure 7.4.1. Reading CAD -files to operate machines.

7.5 Communication between machines

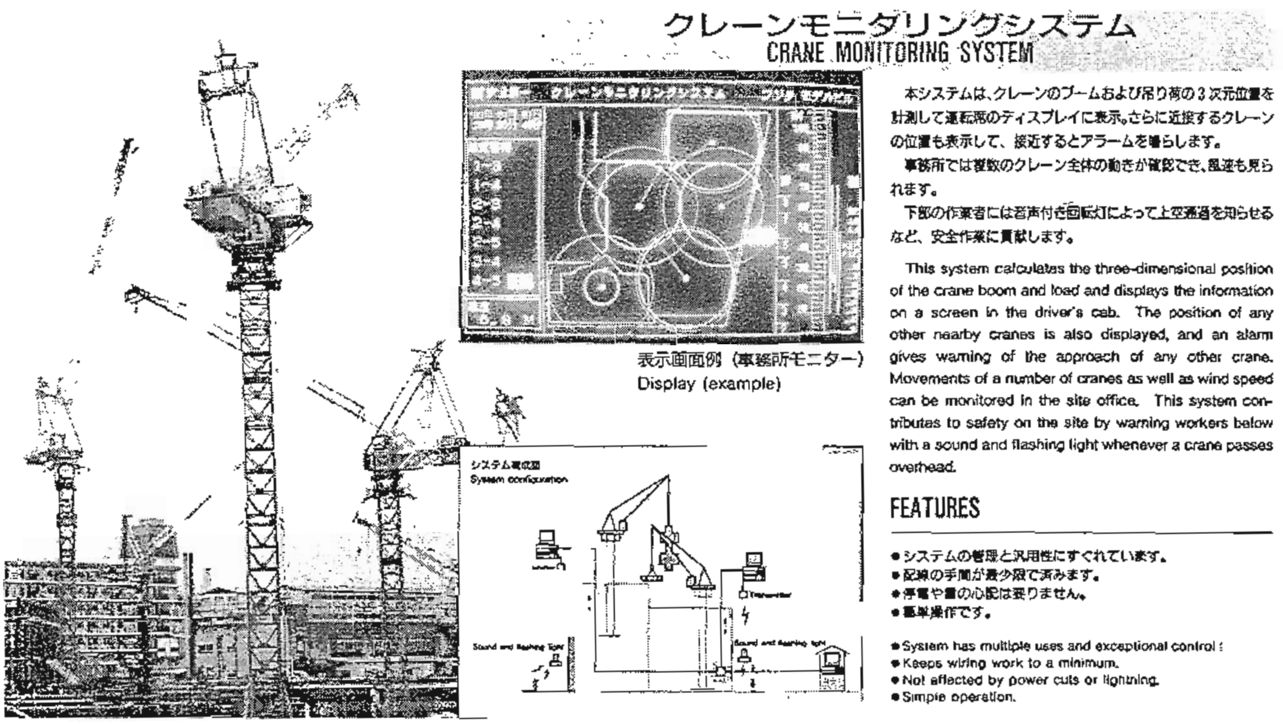


Figure 7.5.1. Information exchanging between tower cranes [Fujita].

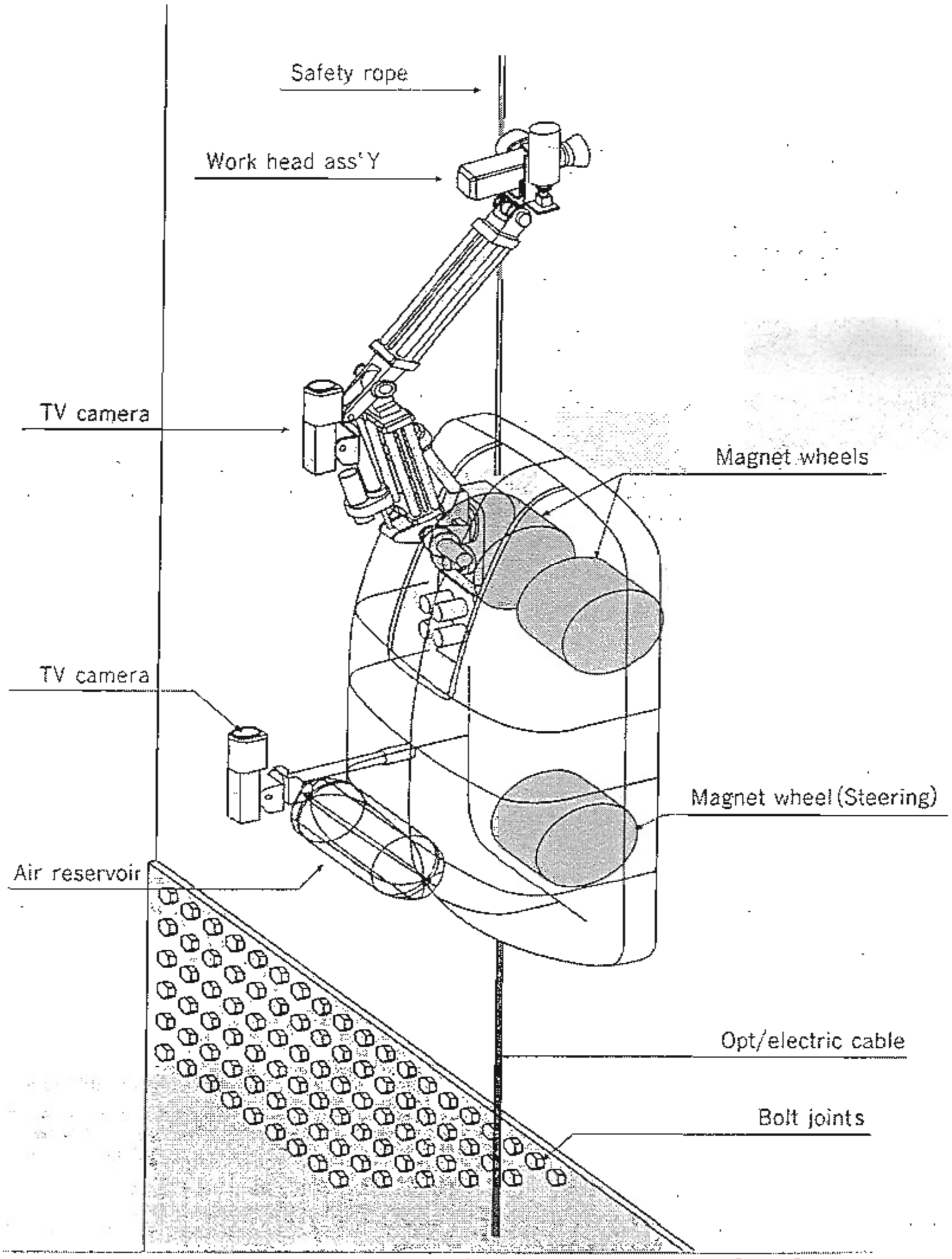


Figure 7.5.2. Information exchanging between components of a robot.
This repair robot developed by the Japan Construction Method & Machinery Research Institute, is used by very large steel structures. The robot repairs and inspects.

8. An Information System for Lifting Tools

Arko Heitbrink.
Eindhoven University of Technology, Faculty of Building and Architecture, Department Construction Engineering and Management.

8.1 The-state-of-the-art

First I would like to introduce myself. I am a student at Eindhoven University of Technology. For my graduation project, I was looking for a project which deals with an international issue in construction engineering. In July 1997, Frans van Gassel told me about Task Group 27. The project that took my interest concerned the state-of-the-art of applied human/machine technologies in countries all over the world. In September 1997, I began my final project, namely to prepare a report on the state-of-the-art in human/machine technology on construction sites.

8.2 Construction engineering

Before a construction company can start to build, a lot of decisions must be made. The decisions are laid down in the construction schedule for engineering the building. In the schedule, the following chapters are always included:

- the costs to produce the building;
- the time to produce to the building;
- how to transport materials to and on the construction site;
- which building method will be used;
- the conditions of labour on the construction sites.

The kind of equipment that will be used to construct the building is influenced by:

- the required quality of the building;
- the costs;
- time pressure;
- experience.

A model the state-of-the-art can be used in this process for making decisions to use particular equipment. To make decisions, the process engineer can use the state-of-the-art model to compare alternative machines. Choices can be explained to other participants in the process to design, construct and engineer a building.

Before you can make a state-of-the-art model of applied human-machine technologies, you first have to make a state-of-the-art model of one human-machine technology. A study of the literature forms the basis for choosing a suitable technology.

8.3 Human-machine technologies

To reduce costs or production time, machines that are used on the construction site must be developed. Human-machine technologies can be divided in several degrees. Figure 8.1 shows three human-machine technologies and their development. The vertical axis shows the amount of energy the machine can take over from the worker, the horizontal axis the amount of control the machine can take over. The development of the machine is high when it is in the upper right corner.

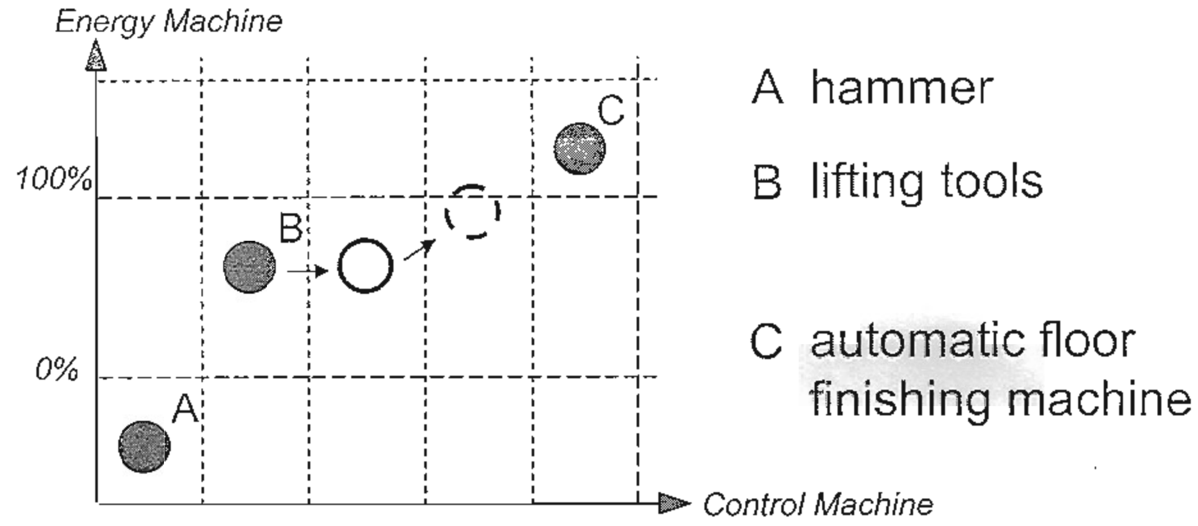
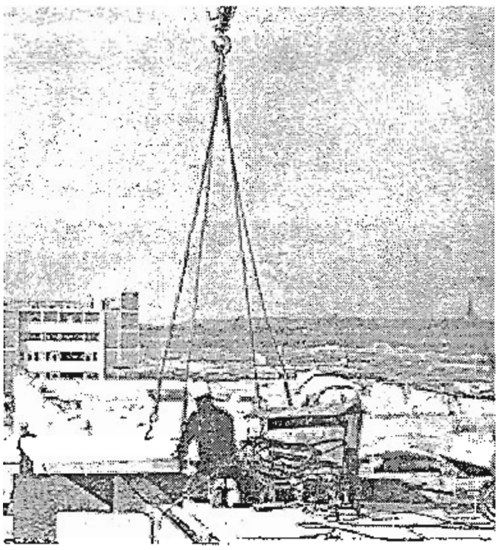


Figure 8.1. The development of human-machine technologies

A hammer is a well-known piece of equipment on the construction site. To use it, a worker needs to put in energy and control. Lifting tools have various degrees of development. Simple lifting tools are, for example, chains that conduct the weight of the element to the crane's hoist (Figure 8.2, left). More advanced lifting tools can give the element the right position or transport the load to a difficult place (Figure 8.2, right). An automatic floor finishing machine can be programmed, the worker has to switch a button and it will do its work. The worker does not have to put in energy and control to finish the floor.



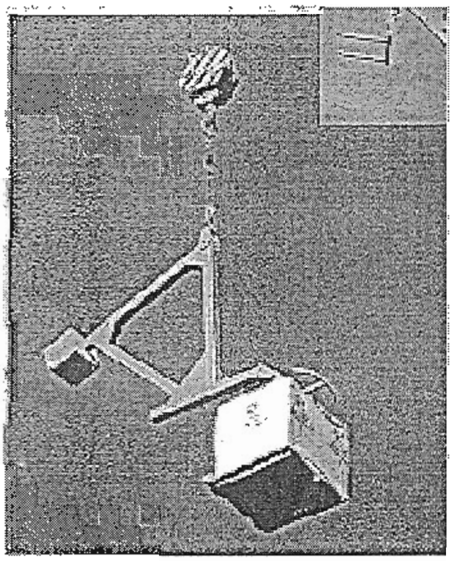


Figure 8.2. Lifting tools[1].

8.4 State-of-the-art

A hammer is a tool that has the same shape, wherever in the whole world it is used. Collecting hammers will not give any new ideas about how to use them. A floor finishing machine is a specialised piece of equipment that can only be used for one activity. The main task is to finish the floor, and differences between these machines are in their cost. They can only be used in very large projects, otherwise they are too expensive.

[1] Montagebau, S. Ludewig (left), RECO Tradecompany (right).

To make a useful state-of-the-art model for a human-machine technology, the equipment should:
- be used all over the world;
- be used in several processes on the construction site;
- play a important role in the engineering process;
- accomplish different tasks in the engineering process.

The state-of-the-art model should:
- give a survey of applied technologies of that particular tool in countries all over the world;
- be a database that can be consulted to solve a construction problem (Figure 8.3).

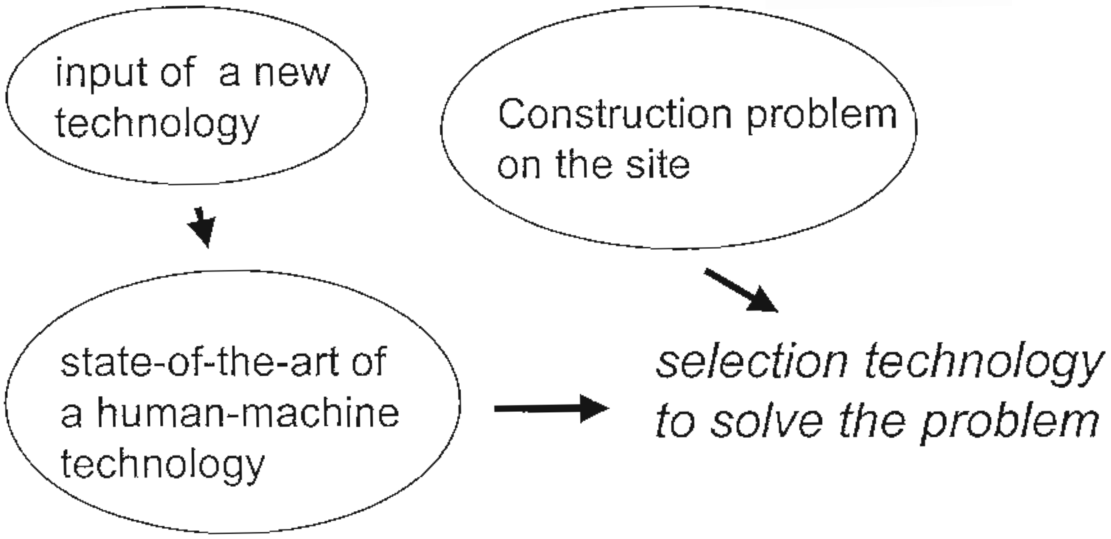


Figure 8.3. The state-of-the-art model as a storage facility for applied lifting tools.

8.5 Lifting tools

One human-machine technology that fulfils these demands is that of lifting tools. Lifting tools will be collected to make a state-of-the-art model. Construction engineers can consult the state-of-the-art model to choose a proper lifting tool for a situation on the construction site.

At this moment, there are no catalogues of lifting tools, only surveys of elements of lifting tools, such as:
- spreader beams;
- equaliser beams;
- chains;
- hooks;
- lifting frames.

With these elements, a lifting tool can be composed. A smart lifting tool is a combination of different elements. For the project, I collected many kinds of lifting tools. Pictures of lifting tools in magazines, books, from the internet and information from construction companies were collected.

All these lifting tools must be saved in a database. It's important to choose the right keywords so the user can consult the database efficiently. The collected lifting tools can be saved by saving their parts or their possibilities. By saving them by parts, the user can compose a new lifting tool out of the collected parts. In the preparation to construct a building, it is not important how the lifting tool looks, but what its possibilities are. A better way to collect lifting tools is to describe what tasks it can fulfil.

8.6 Example situation

An example situation shows how a state-of-the-art model can be consulted. The situation shows the assembly of a prefab wall (Figure 8.4).

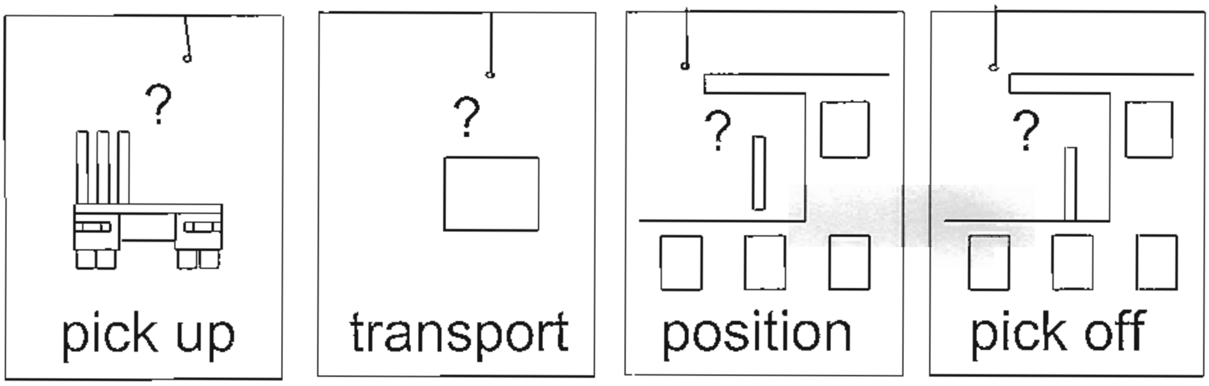


Figure 8.4. Lifting a prefab wall between floors.

The assembly process can be divided into four main activities:

- picking up the element;
- transporting it into its general position;
- positioning the element in the final position;
- picking off the lifting tool.

The lifting tools are collected by tasks. The process engineer has to describe the situation on the construction site in keywords. The state-of-the-art model can compare the keywords of the situation with the keywords of the collected lifting tools.

The situation can be described by the following keywords:

- prefab wall;
- pick off the truck;
- transport between floors;
- positioning by gravity.

Lifting tools that are described by the same keywords will be selected and shown to the process engineer. He or she can decide if the example(s) is (are) a solution for the problem on the site.

The more lifting tools are collected, the more examples the state-of-the-art model will give. The lifting tools shown must be adjusted to the particular situation. The state-of-the-art model only gives examples of lifting tools used in a similar situation as described by the keywords.

A solution for this situation can be a lifting tool consisting of a spreader with a counterweight (Figure 8.5).

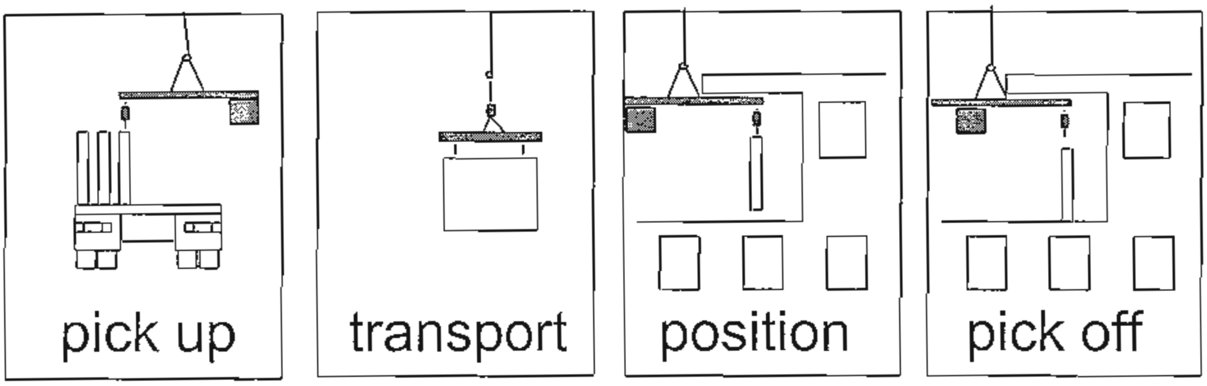


Figure 8.5. A solution for a lifting problem.

8.7 Conclusions

To make a state-of-the-art model of applied human-machine technologies on construction sites all over the world, the following remarks must be considered:

- a state-of-the-art model is only useful when it can be consulted in the construction engineering process;
- its not useful for all kinds of human-machine technologies to make a state-of-the-art model . Some human-machine technologies have already been included in a state-of-the-art model ;
- human-machine technologies must be described by keywords which show their possibilities. How they look does not matter.
- the process in which the human-machine technology is used must be investigated to draw up the proper keywords;
- to keep the state-of-the-art model up to date, a network of people all over the world must be organised;
- one of the people in the network is responsible for maintaining the state-of-the-art.

This project is only an example to give structure to the process of making a state-of-the-art model of a human-machine technology.

8.8 Current situation

The project has now been completed, the final presentation took place on August 25th 1998. The final result is an information system that can be used to collect and consult lifting tools. In addition to a theoretical design, there is an application in 'Microsoft Excel 5.0'. Per activity, keywords can be filled up. The keywords will be matched with the keywords in the database. The result is a list of lifting tools that can probably be used in the situation described on the construction site. The list is a picture of the lifting tools with all the keywords and background information. Background information could be, for example, the company which used the lifting tool, a phone number or details about the lifting tool's construction.

9. Research Projects TG27 members

At the meeting in Munich, the kind of research the members of TG27 would like to accomplish was discussed. The discussion threw up in four themes:

Table 9.1 Research project TG27 members

Fields of Research Themes
Relationship Architecture and Construction. (methods) ■ Design by Assembling ■ Building Systems ■ Sustainability ■
Communication in and around Construction Sites. (information) ■ Equipment ■ Protocol ■
Labour and Equipment on the Construction Site. (subsystems). ■ Mechanisation ■ Robotisation ■ Interfaces ■
Organisational Aspects for Construction Sites. ■ Simulation Building Process ■ Design Tools ■ Technological Developments

These four themes we want to use to structure the research projects. We have asked the members to inform the secretary of TG27 about her research projects. The received information will be placed on the Internet.

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Appendix A

R+D Project outline,

Chair for construcion planning, technology, management and informatics, TU Munich, Arcisstr. 21, D 80290 Munich, Germany, Prof. Dr.-Ing. T. Bock

1989:

Development of a gantry robot for the assembly of customary form stones.
Development of a modular robot control system.
Foundation of the Steinbeis Transferzentrum *"Robotics and Automation in Construction"* with support of the ministry of trade and commerce.

1990:

Integration in the CAD/CAM-Program of Baden-Württemberg.
Project: CAD/CAM applications in construction.

1991:

Study for a Japanese firm producing building machinery: potential for automation of construction in Western Europe.
Further development of the gantry robot system.

1992:

CAD/CAM
Acquiration and beginning of the European research project ROCCO: development of a semi-autonomous mobile building assembly robot.

1993:

ROCCO - Robot Assembly System for Computer Integrated Construction
CAD/CAM
Research assignment from the Allgemeine Industrieforschung AIF: Development of a building construction system for the automatic assembly of stones without binder.

1994:

ROCCO - Robot Assembly System for Computer Integrated Construction
CAD/CAM

The chair for construction planning, engineering and informatics:

The targets are future oriented methods of construction which applicate automation.
Prof. Dr. Ing. / Univ. Tokyo Thomas Bock collaborated in the years 1984 with the Association *"Advanced Construction Technology"* of the MITI (Ministry of International Trade and Industry) on the development , the design, the testing of SMAS (Solid Material Assembly System). He also was member of the Association *"Robotic - Production Technology"* of the Japanese society of architects and a part-time job in the Robot Engineering Group in the research department of SHIMIZU (at this time one of the largest construction firms in the world). He did his doctorate on the theme *"Automatic and Robotic Construction"*

The chair employs three scientific full-time employees and some part time employees.

Research Projects

ROD (Robot Oriented design)

Crucial for the practical design of building parts and an automatic assembly in construction is the development of details that facilitate the application of automation in the means of functionality assembly and production criteria.
Prof. Bock named the practical design mentioned before ROD (*Robot Oriented design*) and published it [Bock88,1], [Bock88,2], [Bock90]. The target of this study was the development of guidelines for planning of construction systems that facilitate the application of robots and automation systems.
Because the lion share of the costs of construction is fixed in an early stage of planning, the final assembly tasks on-site are considered in the beginning of planning and an early stage of development of buildings.
This systematic action for the first time was successfully applied in the design of building parts for the "*Solid Material Assembly System*". The WASCOR group, an amalgamation of twelve building contractors and producers of construction machinery at Waseda-University and several research departments of Japanese building contractors (*Ohbayashi, Takenaka, Shimizu*) are developing automatic construction systems for structural engineering since 1988 following the guidelines of ROD.

Design analysis for ROD

Based on the ROD-concept a design analysis of wing assembly elements for ROD was suggested in [Bock89]. These wing assembly elements are beams and pillars which are fitted with connecting systems. To archive this a systematic method for the analysis of constructive and structural connecting systems is proposed. The target is the development of guidelines for design which can be used to facilitate automation in building and rebuilding.

SMAS (Solid Material Assembly System)

The systematic methods of ROD was applied in the development of building parts for SMAS [IgBo87] on which Prof. Bock worked during his research in Japan. The target of SMAS was the "Automatic Masonry".
The SMAS assembled elements of the size 30 cm * 30 cm * 18 cm using a robot. These elements optimized for assembly are to be fixed 10 to 15 times faster than conventional masonry with the use of an industrial robot.
One problem was that every masonry in Japan has to be reinforced because of the danger of earthquakes. A robot which should be able to lay conventional bricks must have the abilities to handle stones, apply mortar and to insert vertical and horizontal reinforcement. The problem of the application of mortar was solved by the production of exactly measured stones. The reinforcement of the masonry was replaced by the integration of the reinforcement in each brick.
The exactly measured blocks were produced by NIHON-block following the plans of Prof. Bock. To achieve this, existing concrete-stones were redesigned after the methods of ROD. The construction elements are fitted with self adjusting mechanism. They are designed to be handled , positioned, adjusted and fixed as fast as possible.

Analysis to the stage of research in France

The stage of research and technical of construction robotics in France was examined in a study for the *"Centre de Robotique Integrée Ile de France"* (CRIIF) in Paris.To achieve this all accessible activities, projects and programs of the French industry and the French government were analysed [Bock88,3].

Market analysis of cranes

In [Neub92]a market analysis on cranes was made in order to find out which could be integrated in a vertically adjustable scaffolding. It is surprising that there are generally only four different designs. These are a mini crane (a turnable boom with a crab) a SCARA-kinematics, a parallelogram boom and a supple boom.
The choice made was a horizontally moveable SCARA-construction which was mounted in the middle of the scaffolding. A chainlink at the end of the boom was used for lifting. It has to be mentioned that these are manual operated manipulators.

Robot simulation

The simulation of different robot kinematics was made several times with the RobCAD system at the institute. These models would also be available for the applied research project. They make a comfortable off-line programming possible. Therefore the robot will be teached on the computer screen. The work routine is visualised on screen and can directly be transmitted in a robot program in IRDATA-code. Especially logistics and assembly could be simulated clearly. Assembly elements and their functionality can also be simulated.

Steering of a Fanuc-robot with the use of simulation data

This project served to connect the RobCAD simulation system with a SCARA-robot GMFanuc A600 and a KAREL controller with direct PC link using the TDL robot code. The realisation of the data transmission included the exemplary off line programming of a depalettization event with the GMFanuc A600 using the RobCAD system [Sinz92]

Guidance control of an FTS

Along with the *Berghof* firm the institute collected experience in the technical of FTS (automatic guided vehicles) concerning kinematics, navigation guidance control and design of a control of conditions. The kinematics of vehicles known for automatic movement in plain sheds are not researched for construction site movement. such a kinematics was developed, but further alternatives should be worked out.

Automation of tower cranes

Together with *Bilfinger & Berger* and *MAN* experiences were made in the sector of cranes which are crucial for the building and construction industry. The emphasis laid on the standardisation of mechanical plibale position control system, the automatic control of state design of pliable systems and the integrated unlink control of asynchrony motors.
The use of controls of state is difficult, because they are based on mathematic models of the process which should be controlled.
The standardisation made it possible to describe all important robot-axels with mechanical pliability with a differential calculus of 4th or 5th order which are of the same shape and therefore share the same solution.
Important examples are:

- crane-traversemechanism (rope)
- crane-rotaion gear (rope)
- crantower (torsional oscillation)
- linear robot axle (flexural vibration)
- pinion in linear robot modules (longitudinal oscillation)

The theory of control of condition Was developed in the sixties. The suitability for mechanically pliable systems (also concerning fuzzy) was proved. Because of the complications with their putting into operation they can not be found in any robot control system all over the world (ROCCO survey Balgauer 1992).
The problem was solved by developing a purely digital control method which needs no identification of surrounding analogue number of revs control systems.

The design of control of condition is based on mathematic models of control systems. This task of optimization is given by a equation which is the result of the description of the system. But she is not linear and of double order. To find her solution numeric processes are used which work with iterative methods which need unknown calculation time. If they are applied for adaption in a robot control system the robot could possibly change faster his position than his control system does. This problem was removed by solving the differential calculus analytically.

Studies

a) Possibility of automation of construction process in Germany by modification of existing Japanese construction system
b) Market study on the possible use of façade robots
c) Comparison of German and Japanese planning and construction course

AIF - Project: "Joining of stones without binder"

a) Prefabrication robot

A reprogrammable control was developed [Leyh93], [Lehy94], [Grot93] and is used as a test object for several research and development tasks in construction with depend on the possibility of flexible motion programming for the robot. The machine is suited for the assembly of form stones as dry stone [LeGr94,1], [LeGr94,2]. The system consists of a gantry robot a station for the handing over of construction materials delivered and several claw systems. This gantry robot is a good priced modular design which was self-developed. It consists of customary parts like a user configurate system which includes linear elements, servomotors, amplifiers and a VME bus system. The interfaces are fitted with standardised plugs which were developed at the institute to support the modular design.
Several periphery electronics for signal processing like the emergency stop was self designed. A self developed modular software on a PC is used for hybrid[1] control. he system is designed to allow the construction of customary masonry sections (6,9m * 4,9m * 2,5m). Concepts for the needed robot technology and the assembly operations which were theoretically worked out were tested and derived further development [LeGr94,1], [LeGr94,2].

b) Hybrid construction control

Derivations from the planned operations must be considered when assembling building parts. They have to be detected by the sensors of the crew to shift the robot control from automatic to manual mode. The problem has then to be solved by the crew controlling the robot with a joystick. The shifting back to automatic mode is difficult, because only some robot instructions are suited for a re-entry in the program course. In a assembly sequence depalettizing operations are a possible re-entry, because the user is able to decide whether to shift one of the last (changed out) elements or turn back to automatic when assembling the next building part.
The robot control software is given as a source-code in a standard language. It is easy to change the software to control a different grab system, because of the modular design. Strong emphasis was laid on including the data from the sensors in the control software.

c) Construction part design suited for automation

In [BoBlGe92] guidelines for automation suitable planning and design were published.
self-equalizing and error tolerant structures of building parts regarding handling and assembly were developed and tested after the rules described in [LeGr94,1], [LeGr94,2], [Grot93].The inflicted components are grabs and assembly elements. They are used for *"Automatic assembly of customary form stones"* .
The building parts produced following rules mentioned before could easily and fast be dismantled and sorted. The costly separation of the building rubble would no longer be needed because of the exclusive use of the removable joints. This would also be support recycling. The dismantling could (like the assembling) be done by using a tele-operated construction robot. This includes the possibility to leave human workers out of the dangerous and hazardous field of work. costly safety measures would no longer be needed.

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[1] automatic or manual control possibl

d) Development of end-effectors

Manipulators are characterised through the interaction between the end-effectors and the construction material. The task of the end-effectors is to generate this interaction. The flexibility, interaction and reliability of the end-effectors are very important for the workability of the developed assembly procedure.
Because of the need for task specific grabs, three different grabs were designed and built [Grot93}. They could be used for the research project applied for.

e) Observer-draft (substitution of sensor)

An observer of the conditions (digital Kalmanfilter) was implemented to avoid the use of costly force and momentum sensors. This algorithm is able to estimate the occurring forces using the data of the existing measurements (position, velocity, motor current).

f) Assembly procedures: "Joining of stones without binder" Examination of grabbing and joining operations

The application of the robot system owned by the IMB for the automatic assembly of customary form stones was described in [LeGr94,2].The essay is divided into three sections.
The first part]Leyh94] dealt with the techniques of the devices, the second [LeGr94,1] with the assembly elements and the third part [LeGr94,2] with the experimental trial. Form stones are assembled without binder and afterwards filled with mortar. The form stones used are produced by GISOTON and are characterised through small tolerances (0,5mm) and are fitted with conical and oval gaps This features favour automatic handling fundamentally.
The project visualises the problems in the automatic assembly of construction pants when using customary elements and helps to solve them. The *combination* of the individual assembly components (assembly element, robot grab, robot kinematics, sensors, controls) is crucial in this case.

ROCCO - Project

The Robot Assembly System for Computer Integrated Construction short ROCCO (ESPRIT III 6450) is a research project supported by the EC and has the main objective to develop an autonomous, mobile robot for the assembly of masonry on sit. Automation of construction site procedures is made possible by the use of the concept Computer Integrated Construction.
The ROCCO-project serves as a basis for the use of robots in the realisation of individually planned buildings. Main objective is the development of an automation system which includes all areas of planning and preparation of work from the optimized prefabrication of parts to the execution on site. With such a system, productivity and humanity of jobs on site would be improved [BoGeSt93]. The project has been completed in 97. Up to now 3 units of the ROCCO robot have been sold on the market.

Planning of the movement and avoidance of collisions of a robot

In this research project a robot should be used to automatically assemble walls. Typical problems like grabbing the load, transportation to the destination and positioning of the part have to be solved. The movement should avoid collisions. The robot must react to avoid collisions if dynamic objects come in the course of movement. A overall view of the existing motion planners is given in this essay.. The tasks can be divided in normal algorithms, neuronal nets and genetic algorithms [Alic94].

Façade-Service-Implement

Since 1933 the department "Automation " has done research on the field of half -respectively full-automatical maintenance of façades under difrent surface-conditions:
Fields of examination are:
- Height reaching devices
- Ergonomic investigation of facade maintenance
- Cleaning and maintenance methods of different facade surfaces
- Prerequisites for the use of automatic or telemanipulated facade maintenance devices
- Feasability, marketability
- Testing and control by simulation

Aim of the researching-efforts is the development of a semi-automatical façade-service implement for the maintenance and diagnostics of skycraper- façades and other areas of building which are accessible from outside. The implement shall be programmable as well as navigateable by remote-control, and it shall be flexible concerning the tasks (cleaning, diagnostics by camera, maintenance, ...) and the use (suitability for buildings already existing).
Beside first studies concerning the pracability several computersimulations about possible kinematics and working-processes were worked out at the department.
Together with the firm "TAW-Höhenzugangsplanung" from Hamburg, a working pool called "Fassade" was founded to support the research-project and the purpose of information-exchange.
Both institutions are partner in a consortium, which has applied to the European research-program "BriteEuram" for support in the development of a façade-service implement. The application was submitted to the 4th framework with the title "SAFEMAID (Semiautonomous Façade Maintenance Device), numbered BE 95-1487.
Furthermore, there were two national research applications supporting the project-idea in work.
References:
Roboter und Telemanipulatoren für Reinigungs-, Inspektions-, und Wartungsaufgaben an Fassaden und auf Dachbereichen; in: Deutsches Architektenblatt; 11/93
Innnovative Fassadentechnologie - Fassadenroboter für Montage, Diagnostik, Instandhaltung; Kongreß: Internationales Forum Innovative Fassadentechnologie; 2. und 4. November 1994
Fassadeninstandhaltung - Notwendigkeiten und Möglichkeiten; Computer & Bauen; München; 6/95

Information-Logistic

The interdisciplinary project started in 1995 and had a term of two years with the possibility of being prolonged. Seven institutes coming from the fields of mechanical engineering, information science, constructional engineering and architecture are taking part in the project.
In the applied project, a concept of a more efficient Infologistic shall be worked out, so that the communication-structures, especially inside and in/between the middle class firms, can be improved significantly. Development of methods and services for the parallel planning and for the keeping of datas are the targets of that program. In cooperation with the industry, the results of this project will be verified.The research project shall supersede the focal point CAD/ CAM running since 1985. The aim of this focal point was the interdiscipliary exploration of the CAD/ CAM technology in order to make students and the industry acquainted with this technology. The new focal point Infologistic will put emphasis on the organisational aspects of the information processing. The succesfull cooperation of sveral institutes at the university of Karlsruhe shall be continued.

Automation in road construction

The present degree of automation, especially concerning machines for floor compacting and machines for asphaltsurfacings are being researched in several studies.
Together with partners from other European contries a research-proposal concerning the further development of machines for the road construction called CIRC (Computer Integrated Road Construction) was submitted to the "BriteEuram"-program of the European Commision. In this workingprocess optimizing planning data and measuring of the production-process shall be prepared, so that the operator can navigate the road-construction-machine in optimal and with an optimum of quality. The department will be responsible for the preparation of planning data for the operator, ie. producing the shell. and preparing the planning- and process-data in a record for an OFF-line anlaysis for the production process.

Software-Laboratory

For the purpose of establishing a software-laboratory a consortium of proffesorships of the faculties mechanical engineering, architecture, information sience and economics. The aim of the laboratory is an improvement in transfer of softwaretechnologies by organizing a cooperation of univeristy and industry. The transfer extends on two levels:

1) production of practiable software-solutionsfor problems in cooperation between firms and university-partners of different fields of knowledge
2) continuation of the engineer`s studies by courses and by project-cooperation.

A demonstration laboratory offers the opportunity for interested people from the industry to inform themselves about the efficiency of selected software solutions in the field of standard- and special-software.
Aim of this project is the simulation of several building processes for individually planned buildings. This allowes a check of the feasablity of the plan and therefore avoids expensive misplannings. Furthermore, different mechanization variants of building activity can be researched by simulation. Such a simulation is called a "Virtuelle Baustelle" (virtual constrcution site). Apart from the already mentioned avoidance of planning-mistakes, it has got another function in the gradual installation of (partly) mechanized aids, which at this time are very hard to plan (because of the mostly hybrid human/mechanical working method); visalization and simulation of building processes could improve that.

Automation of housing production

Presently an international study is being carried out to analyze the state of art of industrialized housing production and ist potential for providing low cost affordable housing in Germany where the ownership ratio is very low compared to other european countries.

Robotization of wooden elements prefabrication

Presently a study is carried out among national wood construction companies to investigate the future potential of robotic prefabrication of wooden houses.

1998 T. Bock

Technische Universität München, Fakultät für Architektur, Lehrstuhl für Baurealisierung & Bauinformatik, Prof. Dr.-Ing./Univ. Tokio Thomas Bock, D 80290 München, Fon +49(0)89 289 22100, Fax +49(0)89 289 22102, e-mail: bock @ ilk.de

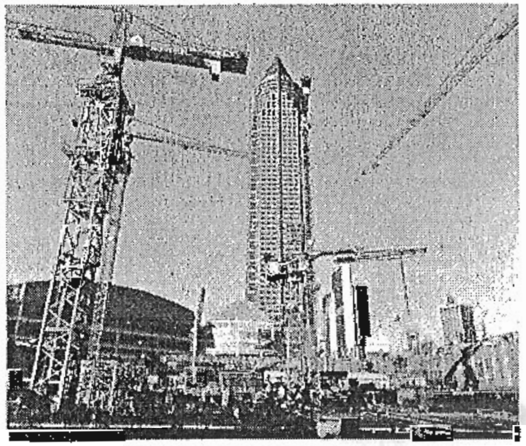
Appendix B MICC-project

The Construction Work

Construction means to erect a whole, a building using many different components, having several companies with many people working together on the same challenge, for the same goal, on the same site.

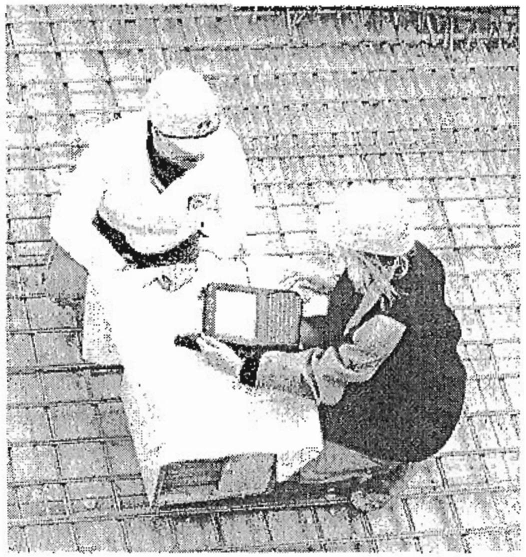
Every construction project is unique. Beginning a new site means for the staff to move to a different location, to start work with different partners on site and off site and to be part of a team. Time is normally short, decisions have to be made quickly, communication is one of the essentials for the every day work not only to solve the every day problems but also to share the same information like drawings, standards and guidelines to make work easier for everyone.

The Construction sector is often at the forefront in making use of leading edge technology. Portable IT equipment and mobile communications technology are today robust and portable enough to be introduced even in this demanding sector.



The Project

The development of integrated communications (wired and wireless) on the construction site is very important for the Construction industry. The today used, walkie-talkie based voice communications have to be developed and capabilities to exchange data have to be added; especially for blue collar people working on site.



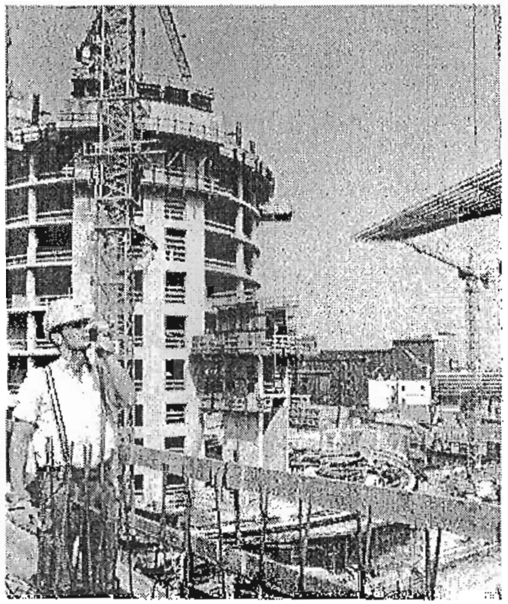
The construction process has to be adapted in real time to what is really happening on the construction site: poor weather conditions, equipment breakdown, late supply delivery, production delays... In order to help not only the site management but also production teams in their daily work, new services like production and supply supervision, rescheduling and tools to aid collaboration are needed. Capabilities to exchange data with company headquarters and suppliers through the combination of wired and wireless transmission have to be added.

The Communications Container

In order to provide the communications requirements of all the organisations with personnel on-site, and given the temporary nature of sites, MICC will prototype the "Communications Container".

This is a prefabricated preconfigured communications hub which is installed at the start of a project to provide on-site wireless communications, communications for the site offices, differential GPS services and links to the outside world.

The prototype will be tested in real projects with real users in four european countries.



Appendix C Sheets Presentation Information System Lifting Tools

TG27

State-of-the-art

of human-machine technologies
on construction sites

Presentation by Arko Heitbrink

TG27

Introduction

- what are human-machine technologies?
- what is a state-of-the-art?

TG27

Introduction

- human-machine technologies are tools which are used by a worker on the construction site

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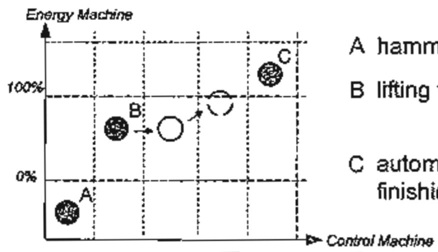
TG27

Human-machine technologies

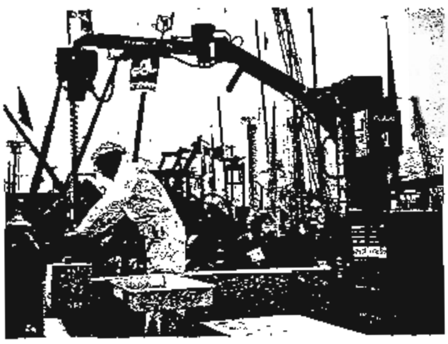


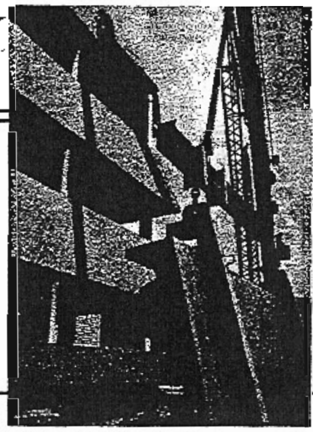
A hammer

B lifting tools

C automatic floor finishing machine

TG27





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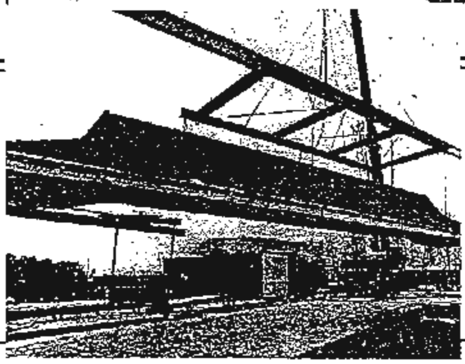

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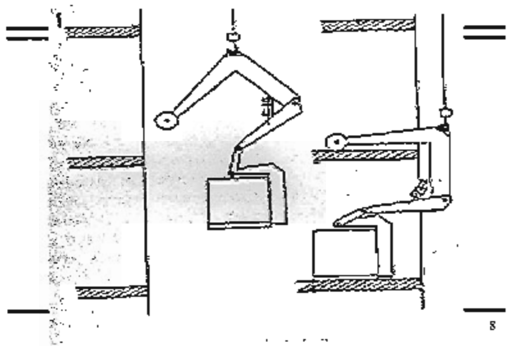
TG27



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TG27
State-of-the-art

- a state-of-the-art is (in this context) a:
  - survey of lifting tools applied in countries all over the world
  - database to consult lifting tools to solve a construction problem

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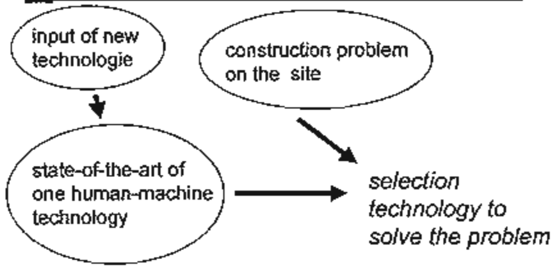
TG27
State-of-the-art



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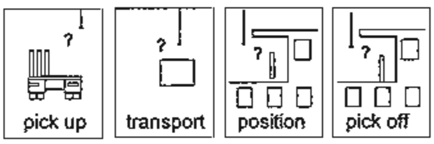
TG27
Example situation



- the assembly process of a prefab wall

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TG27
The assembly process of a prefab wall

- the assembly process
  - is dynamic
  - consists of different partial processes
  - changes during engineering the process

Munich, April 2, 1998 12

TG27
State-of-the-art

- the state-of-the-art
  - is static
  - is a list of applied lifting tools, described by a range of keywords

TG27
State-of-the-art

classification of technologies → fit of classifications = solution of the problem ← classification of construction problems

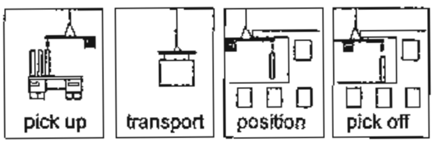
TG27
The assembly process of a prefab wall

- keywords of the construction problem in this example
  - prefab wall
  - pick on off the truck
  - transport between floors
  - positioning by gravity

TG27
The assembly process of a prefab wall

- keywords of the technology in this situation
  - can lift prefab elements
  - can lift eccentrically
  - can position by gravity

TG27
The assembly process of a prefab wall



- solution of the construction problem

TG27
Conclusions

- the state-of-the-art is a database which can be consulted
- the human-machine technologies need to be classified by keywords
- to have benefit of the state-of-the-art the construction problems also need to be classified in keywords

Appendix D Information about CIB

International Council for Research and Innovation in Building and Construction

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CIB General Secretariat:

Office address:	Kruisplein 25-G	tel:	+31.10.411 02 40
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	3000 BV Rotterdam	http//www.cibworld.nl	
	The Netherlands		

CIB is a world wide network of over 5000 experts from about 500 organisations, who actively cooperate and exchange information in over 50 Commissions and Task Groups. Their scopes extend to all fields in building and construction related research and development. They are listed on the next page.

They are actively engaged in initiating projects for R&D and information exchange, organising workshops, symposia and congresses and producing publications of acknowledged global repute.

It is in their ability to bring a multi-national and multi-disciplinary approach to bear on the subject matter delineated in their Terms of Reference that is their strength.

CIB Members come from institutes, companies, partnerships and other types of organisations as well as individual experts involved in research or in the transfer or application of research results. More than 130 Universities worldwide have joined.

CIB is an Association that utilises the collective expertise of its membership to foster innovations and to create workable solutions to technical, economic, social and organisational problems within its competence.

Details on Membership and Activities are obtainable from the General Secretariat at the address above.