BAKKENIST, SPITS EN CO ORGANISATIE ADVISEURS

Amsterdam Den Haag Groningen Eindhoven

Beleidsadviezen Begeleiding Ontwikkeling

CONSTRUCTION TECHNOLOGY 2000

- An inventory of technological developments -

A study done by Bakkenist, Spits and Co, the Netherlands, on behalf of the European Committee.

An inventory of technological developments in the context of the first phase of a study on technological trends in the construction industry.

Ir. W.J.P. Bakens
Th.J.M. Moeskops
Ir. drs. A.P. Dreimuller

November 1984

INDEX

TECHNOLOGICAL DEVELOPMENTS AND TRENDS

This report is part of a study on technological trends and developments in the construction industry.
The first phase of this study, which tries to give an inventory of these developments and trends, uses, as well as the rest of the study, two main information sources, namely literature study and interviews.
In this first phase, on the one hand technological trends are described, checked and completed through interviews, while on the other hand a list of (±150) technological developments is made, based on a great number of publications published in the last few years within the field of construction technology (literature 1-15).
This way of working is part of the methodology of the study and is followed to get a view of the situation as complete as possible.
This report only describes the result of the literature study, while this part of the study has to result in clusters of developments.
These clusters can be used to select technological trends, which have to be compared with the trends resulting from the interview study.
The final result of this first phase will be a list of technological trends which have to be worked out in the next phase of the study.

The first paragraph (§.1) will elucidate the term technology and the difference between a technological development and technological trend.
In §.2 a method for culstering of developments will be given.
A description of each clusters, as well as the relation between the various clusters will be given in §.3, after which in §.4 some conclusions of this inventory will be given.
In the appendix, each of the selected clusters together with examples of technological developments will be described more extensively.

§.1 TECHNOLOGY, DEVELOPMENTS, CLUSTERS AND TRENDS

Before describing technological developments, clusters and trends first the meaning of those terms has to be clear.

Technology is a term derived form the word technique: technique means the skill to execute something, while technology means the knowledge of the various techniques; or more generally, technology is the knowledge of the alternation process, while technique is the skill to execute this process. This description however should be interpreted very broadly: technology is not only directed at physical things such as the working up and processing of materials, but also at matters of concerning management, organization and labour.
To prevent that this study in general, and this report in particular will be confined to the physical description, the term technology has to be circumscribed more precisely. Therefore the ISTA (International Society for Technological Assessment) definition will be used: "Technology is the practical knowledge, used to perform activities which change humans natural and social environment" (16). With this, technical and technological changes are described as improvements on the field of technique and technology.

As already said in the introduction, this report tries to describe the gathering of ± 150 technological developments into clusters by means of literature study. What is remarkable, looking at the enumeration of developments is, that it contains developments of different "levels".
What level means in this study and this context can best be made clear by following example.
When the computer is introduced in the construction branch, the whole branch will be affected by this: computerized estimates, pay-bills and site plans may be the result. Not only the organization of the branch or of the company will notice this, but also the computer and the bricklayer.

When on the other hand this computer gets a pneumatic hammer the result will only be obvious with the computer himself, not with the company or the branch.
So, the level of a technological change depends on the impact it has on the organization of the construction branch, if it affects the whole branch of industry it is a so called macro change; if it affects a company or a project it is a mezo change, and if it just affects the task of a worker it is a micro change.
Now the "level"-distinction in general is made clear, the meaning of this distinction, within the frame of the study should be explained.
In the introduction of this report the two research methods are described, namely the gathering of related technological developments into clusters by means of literature study and the describing, checking and completing of trends by means of interviews.

To understand the use of this bipartition, the more because this study is directed to the future, the terms development and trend have to be made clear.
A technological trend is a change within the frame of society with a fairly homogenuous and integrated character, while a development indicates a more inhomogenuous, subsequent and autonomuous change.

With regard to the level distinction made above, the fault should not be made thinking that a macro change is a trend and a micro change is a development. A trend is namely more than a technological change that effects the whole construction branch, most of the time it is an integration of technological changes that it anticipates to, and fits within the society in general and the market in particular. A development on the contrary may affect the task of worker as well as the whole construction branch, but is as such not that integrated and homogenuous of character as a technological trend.

In this context a cluster of developments must be seen as a help to translate the single and inhomogenuous developments into technological trends: it contains developments that are interrelated and connected and which are of a comparable level.

This comparability may be point of discussions, because the impact of technological developments and renewals is not always known on forehand.
And there are more imperfections: the developments on microlevel are at any rate to be expected, adapted or not. Their enumeration however is far from complete, because it is impossible to mention all developments that are going on.
On the other hand, the macro developments and trends are more complete, but even on the fact if they will ever be introduced, questions may and will rise; now, but certainly in the future.

§.2 A METHOD TO CLUSTER DEVELOPMENTS

By means of literature study a great deal of technological developments are signalized an enumerated. The literature for this part of the study exists out of publications and reports from both inside as well as outside the European Community, and which describe possible technological developments and innovations (2-16). There are a great deal of developments that cover the field of both civil engineering and building industry as well as the various activities of the construction process (design-supply-construction). These developments will not just be enumerated sec, but they will be described within the frame of the various clusters.

As mentioned, this study tries to give a view of technological developments and trends in the construction industry as complete as possible. Would all developments just be clustered and the clusters seen as possible future trends, then a danger exists that developments and/or trends that in the inventory phase are not signalized, will also not be taken into account in a later stadium.
To guard against this a frame, a structure has been set up, in which all technical and technological developments have an own and a unique place, and which covers the complete field of technology. This frame is furthermore also a motivation for the clusters of developments
In this way a classification is made within the un-organized field of developments.

An important and self-evident question now is, what kind of classification has to be made or, with other words, what kind of connection does exist between the various single developments?
The classification may not be based on the characteristics of the developments, but has to be neutral.
To achieve this, in the study the construction industry has been divided on two different ways.

A first division has been based on production factors and a second on the, in this study focused production activities. Although it can be remarked that also other divisions are possible, these two emphasize the relevant factors for the construction industry and are also complete and profusely. So, the requirement for a neutral and complete covering division is fulfilled.

In the construction industry the following, for this study relevant, production activities can be distinguished: design, supply and construction, while as production factors can be mentioned: information, energy, labour, raw materials, equipment, organization and capital. This last factor is not further processed, because it does not come within the scope of the study.

Figure 1.
Production factors/activity matrix

Production factors	Production activities		
	Supply	Design	Construction
Information			
Energy			
Labour			
Materials			
Equipment			
Organization			

To enlarge the quality of the analysis the matrix is further detailled by refering the production factors.

The most known production factors in the past are capital and labour. As already said CAPITAL will not further be elaborated, because it does not fit within the scope of the study; so new ways for financing and subsidizing the construction industry will not be looked at.
With regard to the factor LABOUR, as important aspects health and safety, forms of decision making and cooperation must be mentioned. These aspects improve indirectly productivity and efficiency, and are to divide into developments on the field of working conditions and on the field of work organization. With work organization the various ways of cooperation, the division of responsibilities and the composition of the shifts ar meant.

It is namely well thinkable that for example the composition of the shifts will undergo drastical changes, because the craftsmen want to do more varied work.
Furthermore the need for more multifunctional craftsmen may change the composition of the shifts.
Because the underlying reason for this is not the wish of the craftsmen, but the need for a more fast, flexible and easy to plan infill, such developments are not placed in the factor labour but in the factor organization.

Within the factor ORGANIZATION developments on the field of the production- or company process and on the field of the decision making or the construction process are meant.

The division of the production factor MATERIALS is self evident, because it takes the line of the production process into finished products. First the raw materials must be mentioned (e.g. cement and wood), then the materials produced out of the raw materials (concrete and timber), then the construction elements (wall and window frame) and in the last place the construction components (facade and facade element).

Also is the division of the factor EQUIPMENT based on the practical side of the construction branch, namely: equipment on the site and equipment in the factory, both with the subdivision of small and large equipment.

With regard to the factor ENERGY the importance can be deducted from the fact that energy is needed to win, produce and process materials and to construct and use buildings.
First the energy supply or energy sources have to be mentioned, for example fuels, solar and wind energy, nuclear power, etcetera. These sources can be used passively or actively. Secondly the way on which the fuels and sources converted into energy and thirdly the need and use for energy.

In the last place the production factor, which gets more and more attention in the last few years and without which the process cannot function well, namely INFORMATION has to be further detailled. On the field of information three possible, but theoretical bearers of information are distinguished: figures and characters, measures and forms, pictures and sound.
A more practical, thus a more appropriate division for the construction industry is:

- management;
- communication;
- CAD/CAM.

The elaborated version of the matrix is now shown in figure 2 below.

Figure 2.
Production factor/activity matrix

Production factors	Production activities		
	Supply	Design	Construction
Information - management - communication - CAD/CAM			
Energy - sources - convertion - need and use			
Labour - conditions - organization			
Materials - raw materials - materials - elements - components			
Equipment - site large - site small - factory			
Organization - construction process - company process			

Now, each development out of the enumeration, which is based on the literature study can be placed within the matrix, with the suppossition that each developments has its own and unique place. The classification of these developments now, is a motivation for the clusters.
It will become clear studying the appendix that the enumeration of developments has been processed within each specific cluster description under the head of "examples of technological developments".
For this reason and because of the surveyability in the figure the clusters have been filled in, and not the separate developments.

§.3 CLUSTERS - A DESCRIPTION

As a result of the literature study and, based on the enumeration of ±150 developments, sixteen clusters of developments are found, and in the appendix each of these clusters is more worked out.
In this paragraph only an overview is given:

1. communication: the automatisated information transfer between the various partners and process participants;

2. computer-aided-design: computer support within the design process by means of automatisated drawing and calculation;

3. computer-aided manufacturing: steering and control of the production process of construction elements and components by means of a computer;

4. computer-aided-management on the site: automation of the information and instruction flow of a construction firm towards the various projects and vice versa;

5. integration of computer subsystems: coordination between the design, calculation and administration parts of the various computer systems;

6. flexible automation: variable programming of the production process to get a varied gamma of products against minimum costs;

7. robotica: a machine and tool to execute heavy, dirty, dangerous and monotonous work in a non-stop and accurate way;

8. process coordination: agreements and regulations between the process participant which are needed to organize the construction process in another way.

9. prefabrication of composed components: prefabrication of construction components like integrated facade and roof-systems in a factory, after which they are assembled on the site;

10. exchangeable components: the use of components which can easily be exchanged and replaced, in order to reach a more flexible use;

11. material developments: the developments of new materials and new applications of already known materials;

12. construction systems and methods: new methods to realize parts of construction or even to produce complete constructions;

13. construction tools and equipment: the development of new tools and equipment both for the factory and for the site;

14. health and safety: developments directed at an improvement of the health and safety of the craftsmen in general, and of the craftsmen on the site in particular;

15. energy conservation: the development of energy saving materials, alternative energy sources and energy management;

16. other clusters: single and often more small scale clusters of developments with just little or no relation with other clusters.

If the clusters are now applied to the matrix, the insight in the the effects of and the coherence between the cluster will improve. Opposed to the developments, the clusters do not have an unique place in the matrix; they appear on more places.

Figure 3.

Production factors/activity matrix

Production factors	Production activities		
	Supply	Design	Construction
Information - management - communication - CAD/CAM	communication (1) CAM (3) integration (5) flexible automation (6) process coordination (8)	communication (1) CAD (2) integration (5) process coordination (8)	communication (1) management on the site (4) integration (5) process coordination (8)
Energy - sources - convertion - need and use	energy conservation (15)	energy conservation (15)	energy conservation (15)
Labour - conditions - organization	CAM (3) flexible automation (6) robotics (7) health & safety (14)		management on site (4) robotics (7) health & safety (9)
Materials - raw materials - materials - elements - components	exchangeable components (10) materials (11)	materials (11)	exchangeable components (10) materials (11) systems & methods (12)
Equipment - site large - site small - factory	CAM (3) flexible automation (6) robotics (7) exchangeable components (10) tools equipment (13)	systems & methods (13)	robotics (7) prefabrication (9) exchangeable components (12) systems & methods (12) tools & equipment (13)
Organization - construction process - company process	CAM (3) integration (5) flexible automation (6) process coordination (8)	CAD (2) integration (5) process coordination (8)	management on site (4) integration (5) process coordination (8)

In figure 3 a cluster has been placed in a kwadrant in which direct technological consequences may be expected.
For example: computer-aided-design will only have direct consequences for the production factor information within the production activity design. It will however also give cause to alterations in the production factor information for the supply and construction branch: these branches will get other types of design plans not only qua presentation, but probably also qua context.
In the matrices in the appendix this indirect relation will be indicated too, but in figure 3 this is not done.

After studying the appendix with the description of the various clusters of developments it may become evident, that many clusters have overlaps and connections with each other.
This is mainly because the confines of the different clusters cannot precisely be circumscribed and made clear, and therefore in every cluster description the item "relation with other clusters" has been taken up.
To get a better insight in the relations and coherence between the clusters figure is made. Only the direct coherence between the clusters in reflected in this figure.

Figure 4.
Coherence between clusters

	communication	computer-aided design	computer-aided manufacturing	computer-aided management on the site	integration of computer subsystems	flexible automation	robotica	process coordination	prefabrication of composed components	exchangeable components	material developments	construction systems and methods	construction tools and equipment	health and safety	energy conservation
communication															
computer-aided-design	•														
computer-aided-manufacturing	•	•													
computer-aided-management on the site	•														
integration of computer subsyst.	•	•	•	•											
flexible automat.		•	•												
robotica			•			•									
process coordina.	•	•	•	•	•										
prefabrication of composed compon.								•							
exchangeable components								•	•						
material develop.						•			•						
construction systems and meth.						•			•	•	•				
construction tools & equipment			•			•	•		•	•	•				
health and safety													•		
energy conservat.									.		•				

As already said this figure is meant to give better insight in the clusters of developments, in their connections and coherence with other clusters and it should therefore serve together with the production activity/factor matrix as a basis for further elaboration of there clusters.

It can also be a tool for signalizing possible macro-developments and trends, and thus be the basis for the development of a technological scenario.

§.4 CONCLUSIONS

The main conclusions of this inventory, illustrated by figure 3 and 4, is that a lot of clusters of developments are strongly interrelated and show a great coherence.
This will also be elaborated in the appendix in the description of the specific clusters under the head "relations with other clusters". Clusters of developments on the field of computer aided communication, CAD, CAM, integration of computer subsystems and process coordination are strongly related, as well as clusters of developments on the field of CAM, flexible automation, robotica, prefabrication, exchangeable components, systems, methods and tools and equipment.
Almost all clusters have been mentioned just now and so it can be said that almost all clusters are interrelated: just a very few ones point at rather single and unique developments (health and safety and energy conservation).

A second conclusion is that, apart from CAD, all clusters of developments within the production activity design can also be found within the production activity construction.
Beside the reason for the matrix, namely to elucidate the status of the various clusters by placing them in the production activities and factors, this second conclusion may serve as a base for further elaboration of the separate trends in the second phase.

LITERATURE

1. Wissema, J.G., "Technology Assessment, aspecten onderzoek in het spanningsveld van technologie en samenleving", Kluwer Deventer 1977 ("Technology Assessment, aspects research within the tension field of technology and society").

2. Stichting Bouwresearch, "Technologische en structurele ontwikkelingen in de bouw", SBR-72, Kluwer Deventer 1980 ("Technological and structural developments in the construction branch").

3. The Australian Industrial Research Group and Commonwealth Scientific Industrial Research Organization, "Housing 2000; Technological Forecasting in the Austrialian Building Industry", AIRG-CSIRO-report, 1980.

4. Euro-construct, Séries Fast no. 5, "Les innovations potentielles dans le bâtiment en Europe et leurs consequences sur l'emploi", rapport Euro-construct 1982 ("Potential innovations in the construction branch in Europe and its consequences for the employement").

5. Fédération Internationale Européenne de la Construction, "Construction and the third Industrial Revolution", FIEC-report 1983 by mr. R. Mourareau.

6. Stuurgroep Innovatiegericht Onderzoek Programma, "Basisdocument + Bijlage IOP-Bouw", IOP, Den Haag, 1983 ("Base document and appendix of the Innovation focused Research Program").

7. Wetenschappelijk en Technisch Centrum voor het Bouwbedrijf, "Verslag over de bijzonderste activiteiten en vooruitzichten", WTCB 1984 ("Report on the most important activities and previsions").

8. Centre Scientifique et Technique du Bâtiment, "Mise a Jour de l'Inventaire des Technologies Utiles dans la Construction de Logements Neufs", CSTB-report 1979 ("State of the art of the current technologies used in the housing industry").

9. Eurobuild, "l'Art de Construire: Perspectives d'Avenir", report of Eurobuild symposium held in Scheveningen (the Netherlands) 1984 ("Construction: Previsions for the future").

10. Construction Industry Development Council, "Canada Constructs; Capital Projects and Canadian Economic Growth in the Decades Ahead", CID Ottawa 1984.

11. Commission des Communautes Europèennes, "La Construction en Tant que Systeme Industriel; Projet de Programme d'Action", CEE-DG III IC/3, Bruxelles 1983 ("Construction as an industrial system; Draftaction Program").

12. Plan Construction, "Report présenté par le Groupe des Technologes au comité directeur du plan construction", report no. 176, 1977 ("Report of the technology department to the director of the construction department").

13. Ministères de l'Urbanisme et du Logement, des Transports, de la Mer et de l'Environment, "Le Point du Génie Civil; l'Art de Construire; Tendances et Perspectives Actuelles", DAEI-report 1982 ("Cicil engineering; Construction; Actual trends and perspectives").

14. Ministères de l'Urbanisme et du Logement, des Transport, de la Mer et de l'Environment", Le Point du Génie Civil; Etat de la Connaissance", DAEI-report, 5 tomes 1982 ("Civil engineering; State of knowledge").

15. Swedisch Council for Building Research, "The Swedisch Building Sector in 1990", SCBR, Stockholm 1983.

16. The Business Roundtable, "More Construction for the money", reports of the construction industry cost effectiveness project, New York 1983.

APPENDIX

In this appendix sixteen clusters of developments are described. The developments are based on literature study, while the clustering of these developments is, as already said in §.2, based on the matrix as shown in figure 3.

Each cluster description is divided in five parts:

First the purpose of the cluster is given; secondly the technological content of the cluster, as well as the target group is described. Thirdly the relation with other clusters is given, to show the context of the specific cluster.
In the fourth place examples of technical and/or technological developments indicate what should be thought of, viewing the clusters, while in the last place examples of effects and using possibilities give the consequences of these developments.
Furthermore the matrix as introduced in §.3 is added after each cluster description. The reason for this is that in this matrix for each specific cluster the fields can be indicated in which direct and indirect consequences and/or changes will occur. This will be done by hatching: direct consequences or changes are double, indirect only single hatched.

MICRO ELECTRONICS

The use of micro-electronics in the construction industry is now still in its first stage, but it may be expected that in the future the effect on the organization will probably be very far-reaching.
The use of micro-electronics, or more popular of the computer in construction companies has for long been limited to administration, and in some countries now and then to planning. Through the micro-electronics the use of the computer has gone into a new phase: cost-reduction, project management, management on the site and labour planning have come within reach. Also are the possibilities of the computer on the field of computer-aided-design (CAD) and computer-aided-manufacturering (CAM) drastically enlarged.
This has resulted in a more intensive study for the new possibilities of the computer in the construction industry through which the generally assumed backlog will soon be recovered. Therefore the use of the computer in the construction industry is a favourite topic of most governments to stimulate this branch by means of innovation-focused research programs.

Micro-electronics is a collective noun for various applications. These applications do not only differ from branch to branch but also within the construction branch itself.
To get a better insight in the broad field of micro-electronics in the construction industry, a classification has to be made for the different parts.
Although among experts no consensus exists about this classification, the following one is chosen. This because it takes as a starting point the practical value and therefore fits best within the frame of the study, as mentioned in the introduction of this report:

1. communication and information transfer between the various partners in the construction process;
2. administration and management of firms of the construction branch;
3. computer-aided-design including cost and energy calculation;
4. management on the site, including construction and labour planning, materials management and inspection;
5. computer-aided-manufacturing;
6. management of the building stock in general and maintenance management in particular.

In figure 5 the above mentioned applications are segmented to the main parts of the construction process on the one hand and to the process participants on the other hand.

Figure 5.
Computer applications in the construction process

Process phase / Participants	Design and project preparation	Construction	Use
principal			maintenance management (6)
architect	computer-aided-design (3)	computer-aided-design (3)	
advisor	computer-aided-design (3)	computer-aided-design (3)	
contractor	administration and management (2)	administration and management (2) management on the site (4)	maintenance management (6)
supplier	computer-aided-manufacturing (5)	computer-aided-manufacturing (5)	

This matrix is meant to give a more clear view of the place of the specific applications within the construction process.
It will be noticed that communication has not been used in the matrix, but this is because it should be seen as an intermediairy between all process participants at all phases of the process.

Administration and management within single firms is already the most applicated computer facility in the construction industry and therefore no spectacular changes or developments are to be expected. So, it will not be regarded as a cluster of new technological developments, the more because it is not a specific construction branch application.
This also counts for the maintenance management: based on maintenance programs of the automobile and computer industry, this part is also worked out for the construction industry. Although it is becoming a very important application, it does not mean much more - technologically seen - than an extensive software package. As examples of these applications the following developments can be mentioned.

<u>Administration and management</u>:

- global cost calculation
- budget and cost calculation
- purchases
- capacity planning
- budget control
- salary cost control
- materials cost control
- subcontractor control
- building site cost control
- salary administration
- bookkeeping and accountancy
- work surveys
- acquisition
- market-data and -information

- investment survey
- liquidity control
- capital cost- and financial planning
- materials management and other forms of resource planning

Maintenance management:

- registration of complaints
- maintenance schemes
- exploitation cost control

Beside the four other applications (communication, CAD, CAM, management on the site) also the integration of the various subsystems into one system will be described as a cluster in the following paragraphs. This is done because probably a serious danger for the construction industry will be the non co-ordinated development of the subsystems. Big effort should therefore be put in developing an interconnected and co-ordinated system, in which all subsystems fit: only then the developments will be most profitable for the construction industry.

As last remark it should be mentioned that not the complete field of micro-electronics is described, but that a lot of developments are the application of micro-electronics. For example the instruments for dimensional control in constructions, further elaborated in cluster 3 (tools and equipment), are a combination of laser- and computer technology.
With regard to another development on the field of inspection it can be stated that the television systems (i.e. systems which control sewers and other pipes on stoppages, subsidizes and inequalities by means of a TV-camera) are a combination of microelectronics and television techniques.

As last example of a not yet described application of micro-electronics the so called "smart buildings" can be mentioned. This are buildings which are completely steered and controlled by means of computers with regard to energy, fire-safety, burglary etcetera.

So, the use of micro-electronics as a tool in the construction industry makes the field even more extensive than above described.

CLUSTER 1. COMPUTER-AIDED-COMMUNICATION

Purpose

Achieving a faster and better information transfer and a more complete cooperation between the various parties of the construction process by means of the computer.

Contents

The construction process requires the cooperation of various parties. To make this cooperation effective, a lot of the internal communication is needed.
So, the demand for a good cooperation and communication is a precondition for the satisfactory passing off, of the construction process.

In the figure below the project communication between the various parties is shown.

Figure 6.
Communication between process participants

participants	participants	architect	cost-advisor	constructor	electrician	contractor	sub-contractor	supplier	national government	local government	consumer/client
principal											
architect	•										
cost-advisor	•	•									
constructor		•	•								
electrician			•								
contractor	•	•	•	•	•						
sub-contractors				•	•	•					
supplier				•		•					
national government	•			•	•	•	•	•			
local government	•					•			•		
consumer/client	•					•			•	•	

It appears - because of the many dots in the figure - that a lot of communication channels are used in the construction process. Looking at the contractor it is obvious that he has to maintain contact with all participants, so for him the communication aspect is very important.

The most weighty requirement for information transfer and cooperation is to avoid misunderstandings and confusions between the participants. A well-functioning information systems is therefore necessary, which has to be set up and controlled carefully to let the participants not experience any obstacles.
To improve the current information system, it is possible and even evident, that in the era of micro-electronics, this system is automised. The "computerized" information, which is relevant for the participants, contains three different fields:

1. transfer of general knowledge, (e.g. from research and development to individual companies) instead of, or in combination with traditional reports;
2. transfer to technical information and technical drawings on building projects;
3. transfer of product information, including information about regulations etcetera, which tends to go to some sort of product information system.

This communication and information transfer may ultimately result in major changes in the organization of the decision making process. Eventually this may lead to changes in the rates and responsibilities of the professional disciplines in the construction industry.

Relation with other clusters

Because communication is the one and only way to be in contact with other persons, and because this contact is, due to the strongly segmented process, one of the main-issues in the construction industry, the relations with other clusters is enormous: computer-aided-design and manufacturing is a tool for better communication between contractor, designer, supplier and client and vice versa; management on the site is a matter of an improved communication between the contractors office and the project site and between person on the site; process coordination is a pre-condition for a better technical communication, while improvement of communication is a pre-condition for a more effective use of the results of research on materials and products.

Examples of technological developments:

- telecommunication: communication between the various partners on all kinds of knowledge for example by means of modem-connections;
- computer networks: networks of computers between the various partners of the process;
- integrated computer systems: systems that can process all kind of different data into one integrated source of information.

Examples of effects and using possibilities of these developments

- more participation of other than the usual process partners (e.g. the client) within the construction process;
- product information system: system which contains information on all kind of products and materials including information or regulations, codes, etc.

Figure 7.

Possible changes and consequences as result of computer-aided-communication

Production factors	Production activities		
	Supply	Design	Construction
Information - management - communication - CAD/CAM			
Energy - sources - convertion - need and use			
Labour - conditions - organization			
Materials - raw materials - materials - elements - components			
Equipment - site large - site small - factory			
Organization - construction process - company process			

direct consequences

indirect consequences

CLUSTER 2. COMPUTER-AIDED-DESIGN

Purpose

Supporting the design process at the various phases and translating the results of this process into the ultimate design plans, by means of the computer.

Contents

Design plans are of the utmost importance for the construction process. Almost all object information for a construction is given by design plans, not only by and for the architect, but for all participants. The advantages of drawing by means of a computer are the same as of word processing: it goes fast, accurate, changes are easy to process and the output can be in all kind of formats, scales and combinations. But, computer-aided-design offers a lot more than only drawing capacities, in fact, drawing is only the result of the whole computer-aided-design process, which generally exists of:

- analysis;
- synthesis;
- evaluation (integration of drawing, calculation and data-array).

Analysis contains the searching, clustering and relating of data, that are relevant for the design problem. It is a more mathematical technique.

Synthesis is the establishing of formal hypotheses which are based on the results of the analysis. Possible alternatives are given for the global floor-plan, for global structural, physical, functional and also esthetical demands and even for the construction.

Evaluation stands for finding the optimal design: the possible alternatives are represented, measured and evaluated against the light of the program of demands. They are not meant to change or renew the design, but to get the quantitative effects of a design, and what is more of changes in the design.

To use the CAD-system on the most effective and most profitable way, these three design steps have to be internally exchangeable. So, integrated systems are needed. Although a certain level of integration has already been reached, further research is still going on. The effects of such system are already mentioned: quantitative advantages with regard to the presentation of the design plans.
The automation of the analysis, synthesis and evaluation process however, also means a qualitative advantage for the design process: because of the possibility to produce alternatives the ultimate design plan can result in lower investment or direct costs, in lower housing costs, in a more functional organization, in more safety and in an easier or faster construction process. One important precondition with regard to the use of CAD has to be made, namely that education and schooling is provided- In several EC-member states this is taken care of sufficiently, in others no attention is paid to this factor.

Relation with other clusters

The design is the base for each construction and building, and design plans are an important intermediary between the various process partners. Therefore it is evident that the number of relations with other clusters is legion: computer-aided-design is a tool for communication as well as for process coordination, while flexible production automatization and prefabrication of composed components can only be processed renumerative through the use of CAD-systems.

Examples of technological developments

CAD within:

- function analysis
- program of requirements
- urban planning
- architectural design
- constructional design;
- temporary constructions;
- installation design;
- workplans; details; planning schemes (PERT, CPM etc.); product design.

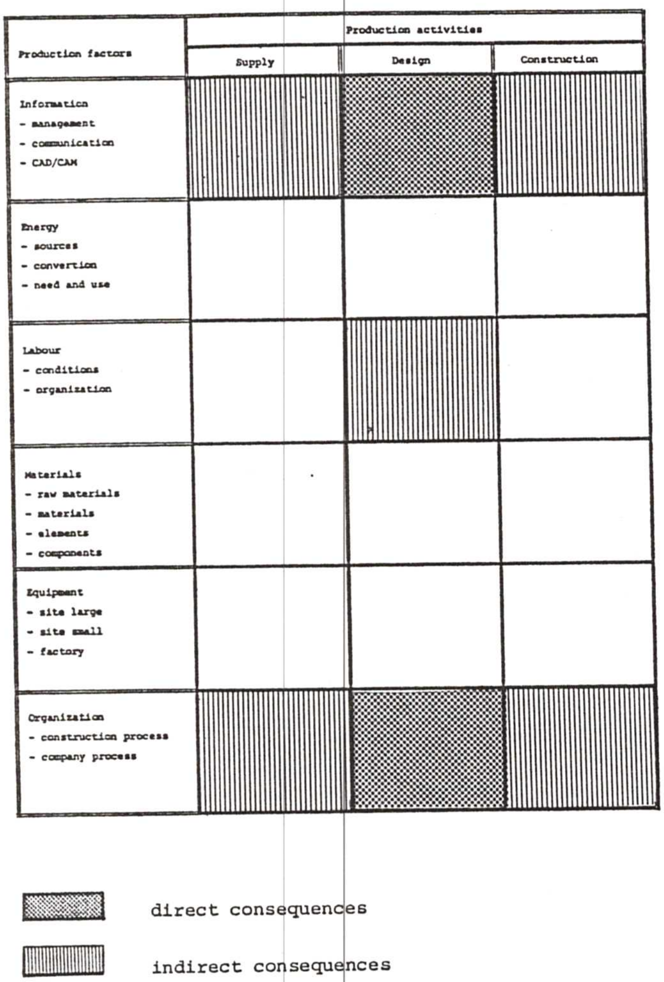
- Fifth Generation Computer Systems (FRCG) is the term for hyper fast, very large qua capacity and very small qua volume computer systems. The will have its effect on the whole field of micro-electronics, but on CAD-systems in particular, because graphical systems need a very large capacity.

Examples of effects and using possibilities of these developments

- integrated systems: there are already systems that show (i.e. let hear!) the accoustical effects on a specific place in a room on account of changes in the design of this room. This example shows the possibilities an thus, what may be expected in the future;
- more participation of other process partners, for example the client: reading design plans and translating them in an existing building is for non-professionals very difficult. CAD-systems, however, can make the design much more imaginable e.g. by means of perspectives.

Figure 8.

<u>Possible changes and consequences as result of computer-aided-design</u>



CLUSTER 3. COMPUTER-AIDED-MANUFACTURING

Purpose

Manufacturing construction elements and components in a factory and supporting the production process by means of a computer.

Contents

In the supplying firms production of construction elements and components takes a central position. Computer-aided-manufacturing offers the supplying firms the facility to improve the production process. The use of the computer in this process in directed at:

1. programming of the machine;
2. control of the machine;
3. control of the product;
4. information transfer about the machine;
5. information transfer about the quantity and quality of the products.

Results of this way of manufacturing are: less fabrication faults, a better choise and utilization of materials and a better quality control. Also does it offer possibilities to reduce the price of the product, to increase the production and to improve the working conditions. This last aspect gets a lot of attention and experts do not agree yet on the social effects of CAM: although heavy and sometimes even dangerous work is now taken over by a machine, a lot of dull work has to be done, because of CAM-systems.

Relation with other clusters

It is difficult to describe CAM as a separate cluster, because it is often applicated in relation with other clusters.

Integration of CAD and CAM-systems makes it possible to take the production aspects more into account in the design process in order to change the production gamma or the production process in a more efficient and fast way.
This integration may lead to flexible automation and therefore CAM can be considered as a precondition for it.
Another relation can be established with regard to robotics or telechiry: if CAM is used in combination with self-acting, self controlling and/or self correcting machines CAM can be seen as an integrating part of robotics.

Examples of technological developments

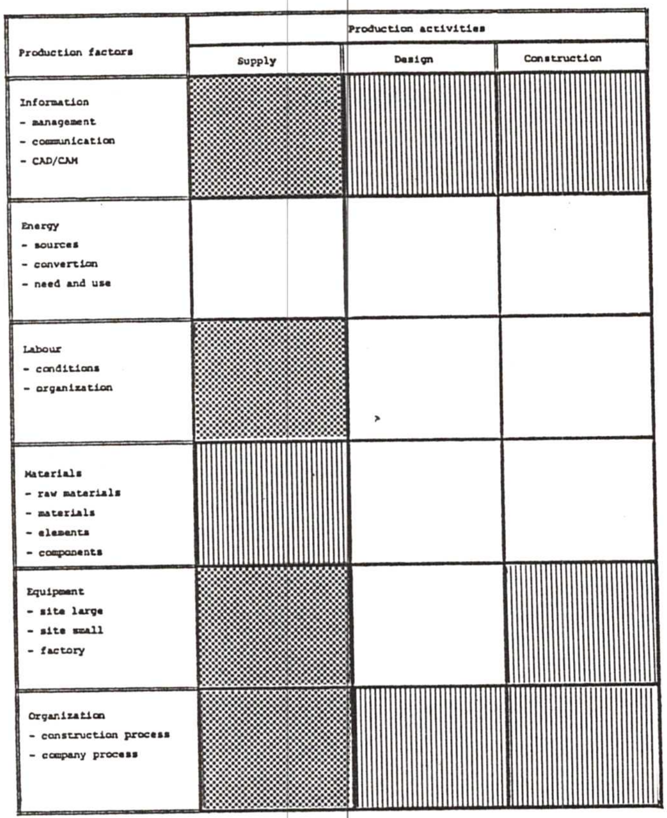
- steering and controlling of machines;
- call down: the conversion of product orders into a production plan;
- instruction and work organization.

Examples of effects and using possibilities of these developments

- improvement of the resource planning in general and a more consciouss inventory planning in particular.

Figure 9.

Possible changes and consequences as result of computer-aided-manufacturing



direct consequences

indirect consequences

CLUSTER 4. COMPUTER-AIDED-MANAGEMENT ON THE SITE

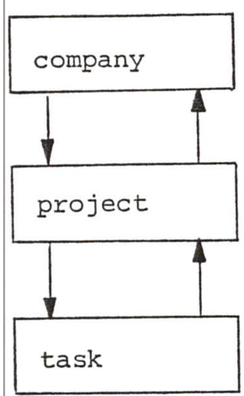
Purpose

Supporting the management on the site, improving the information transfer between project and construction firm and vice versa, and improving the information transfer on the site as such.

Contents

The efficiency of a construction firm heavily depends on a good functioning of the site system. The information transfer between the site and the firm is therefore the most important intermediary. Furthermore the information transfer on the site as such is an important factor to steer and control the project.
In this context it is therefore possible to distinguish four separate information flows:

Figure 10.
Construction projects information flow



Information about material purchases, equipment and labour availability, about sub-contractors,the principal c.q. architect is passed down from firm to the project manager, who direct his instructions to the workers.

In this process however also a feed back takes place: the construction workers report the site manager about the progress of the job, about difficulties and possible needs.
The site manager passes this information, in combination with aspects, such as total hours worked, plant costs, stock, and needs and wishes to the company, which has to take care of all this.

The volume of this information flow often forms the major obstacle for the well functioning of the site system, with all possible consequences. Through developments on the field of micro-electronics computer-aided-management on the site has become within reach. But what is more, because of the growing need for accurate, available and up-to-date information the onsite computer will become essential.

Relations with other clusters

Management on the site is an important aspect within micro-electronics and therefore much relations with other clusters can be noticed. Changes in the design, which occur more as the project becomes larger, are of great importance for the construction management on the site and so an cooperation between CAD an the onsite computer could improve the situation drastically.
When flexible automation becomes possible on the onsite computer can order its purchases directly related to current needs, so the firms office could for this aspect be shipped out. In this way stocks can be kept at a minimum level, with regard to the companies office as well as to the site.

Examples of technological developments

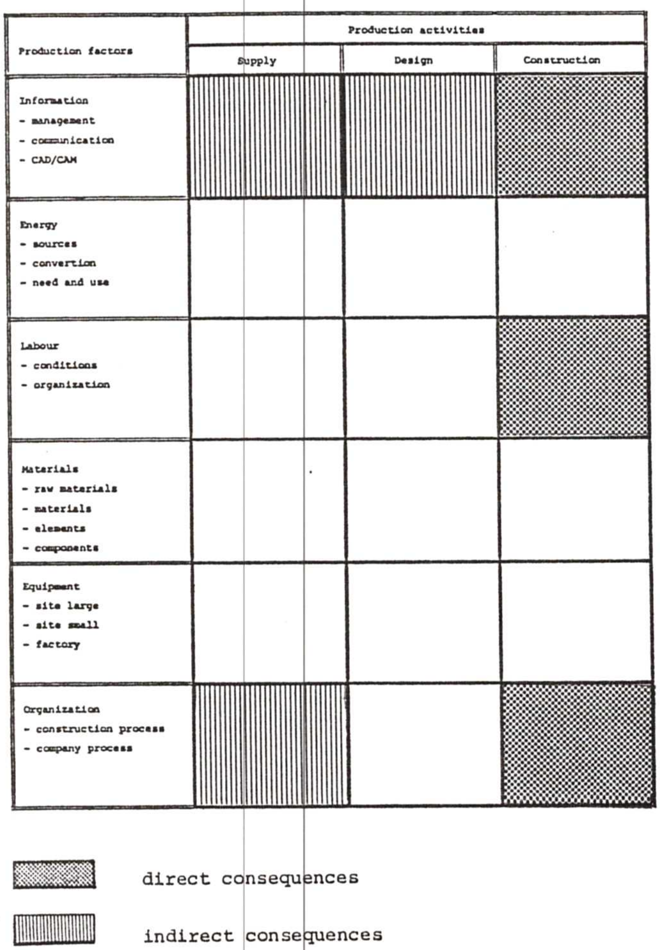
- computerized site plan: optimal planning, given the environmental conditions, of the site, with regard to entrance of the site an place of the equipment and site huts;
- dimensional control plan: planning of the best place to start with and to control the construction, to get a variety in measures as small a possible;

- installment payments: control if principal pays his installments conform the progress;
- inventory and stock control;
- quality control;
- progress control.

Examples of effects and using possibilities of these developments

- terminal on the site;
- computer accustomed site managers and later on even computer accustomed site personal;
- computer networks.

Figure 11.
Possible changes and consequences as result of computer-aided-management on the site



CLUSTER 5. INTEGRATED COMPUTER SYSTEMS

Purpose

Integrating the various computer subsystems to improve the subsequence of the various process phases, the communication between the various partners and the subsequence of the various company phases in the construction industry.

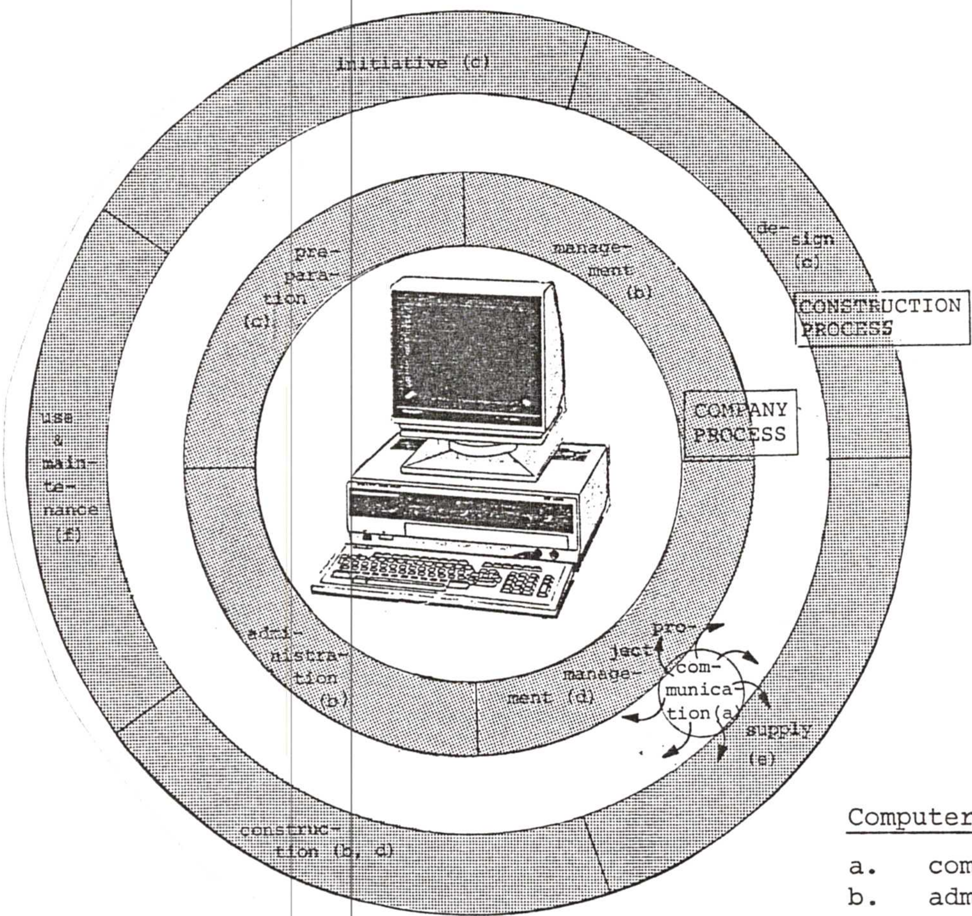
Contents

In the preceding paragraphs some subsystems have been described in the light of their specific contents and use.
But as already said in the introduction, special attention has to be paid to the integration of these subsystems.
This integration will improve the subsequences of the process and company phases, as well as the communication between the various partners. This, on its turn will lead to a better process control and a better product. It is namely assumed that a synthesis and integration will lead to more productivity improving and effective results, than the separate effects of the separate trends.
Therefore it is necessary to distinguish within the field of the construction industry two different processes:

1. the construction process, which has been described in the introduction, as the sequence of activities (initiative, design, construction, use and maintenance) and the subsequence of partners (principal, architect, advisor, supplier and contractor);
2. the company process: the organization of the succeeding steps within the construction firm, namely: preparation, management, project management and administration.

The figure below shows the desirable situation.

Figure 12.
Process integrated computer system



Computer applications

a. communication
b. administration & management
c. CAD
d. management on the site
e. CAM
f. maintenance management

In the proposed system not only the computer applications with regard to the construction process are integrated, and not only the applications with regard to the company process, but also both processes as such are internally integrated.

As intermediary the computer aided communication will function. So, the need is quite clear, but the solution for it the less. What in this phase already can be stated is that agreements have to be made between the various partners about definitions, descriptions and presentation, and that a coordinating system such as a process oriented form of dimensional coordination may be part of the solution.

Relations with other clusters

The relation of this cluster with the "computer clusters" (1 till 4) will be obvious and therefore not further circumscribed. However, it can be stated that a precondition for achieving an integrated system is the cluster process coordination, because of the needed agreements. Also may an integration of CAD and CAM create the possibility and/or an opening for the cluster of flexible production automation.

Examples of technological developments

- integrated computer systems;
- national or international data banks.

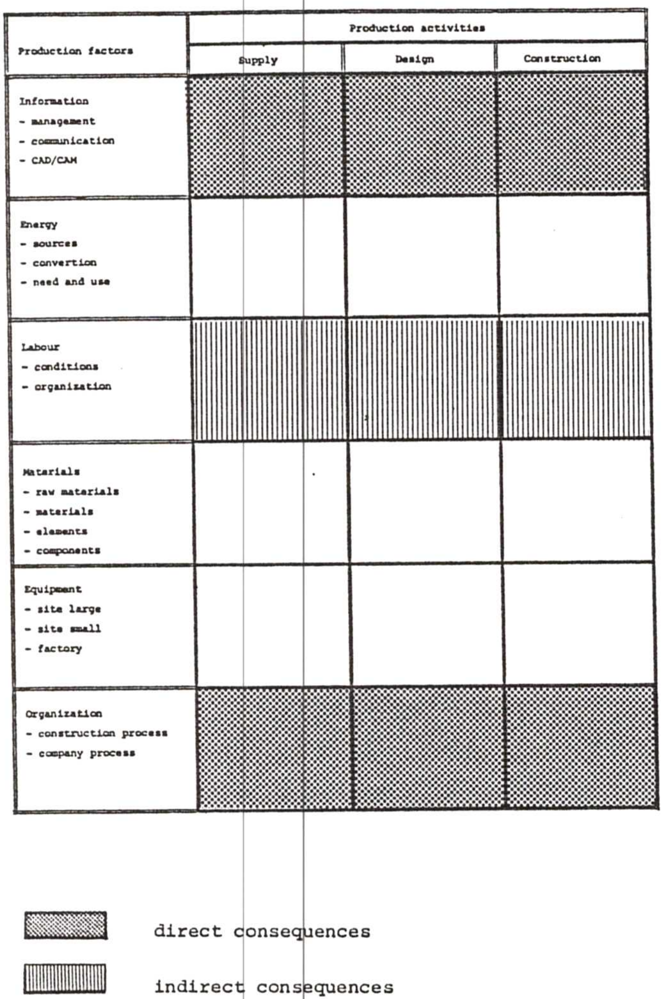
Examples of effects and using possibilities of these developments

- better cooperation and coordination of the construction and company process;

- the need for a form of process coordination or standardization.

Figure 13.

Possible changes and consequences as result of integrated computer systems



CLUSTER 6. FLEXIBLE (PRODUCTION) AUTOMATION

Purpose

Automated production of various heterogeneous products in smaller series within the same production system, which have the same costs as comparable products of a mass production system.

Contents

Opposed to the conventional "hard" or "fixed" automation which contains the production of homogeneous products in large volumina, the possibilities of flexible automation or flexible production automation has come within reach: a non stop, continuous production stream of small, internally, heterogeneous yet congenial products. The heterogenity which characterises the variable production, inplements a limited use of the production apparatus which results in relatively high inefficiency losses. It is possible however to reduce these losses by means of:

a. flexible automation;
b. the so-called "Japanese systems".

Ad. a. One and the same machine performs with the same efficiency as in a homogeneous production process, a number of activities for different heterogeneous products. This is made possible through the variable programming of the computer.

Ad. b. The Japanese systems have some kind of pattern card of possibilities, which can be used in various combinations. In particular the limitation of the several inventories, which are inevitable because of the non-optimal coordination of the different stages of production, is emphasized.

The main purposes of both systems are:

- consumer oriented production of small scale series;
- elimination of inventories, especially directed to the buffer inventories in the production process ("zero-stock-principle");
- quality control during the production process and quality control of the product.

At present, in the construction industry, or the equipment to reach maximum flexibility is very expensive or the flexibility using cheaper equipment, is limited.
So, for the construction industry the tendency is to use more or less cheaper equipment, with some degree of standardization.

Relation with other clusters

To provide the market with more variated and little scale products flexible production automation may be a solution. Although this development is still at its infancy for the construction industry great expectations are cherished. These expectations are mainly fed through the developments on other fields: CAD- as well as CAM-systems are almost a precondition for flexible automation while flexible automation, certainly in this stage, needs a certain process coordination. Also may developments on the field of materials open new ways and possibilities to use flexible automation. As last fact, the relation between prefabrication of composed components and flexible automation must be mentioned: oftenly seen as two opposite trends a growing need for synthesis can be established.

Examples of technological developments

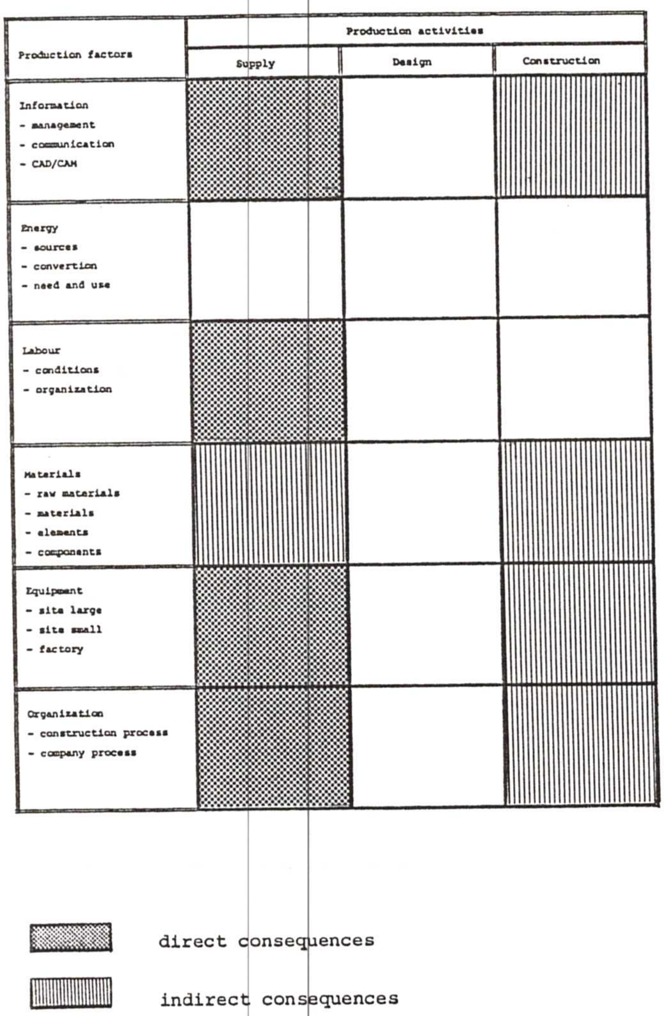
- flexible production automation systems;
- JITP/JISP-systems (Just in Time Production and Supply systems) or also called "Japanese systems";
- MRP-systems (Materials Requirement Planning): a planning system to optimalize material resources;

- Kanban-systems: another form of supply and inventory co-ordination.

<u>Examples of effects and using possibilities of these developments</u>

- demand for better educated personal;
- smaller factories and production rooms;
- adaptation of the transport equipment;
- enlargement of the infra-structure.

Figure 14.
<u>Possible changes and consequences as a result of flexible (production) automation</u>



CLUSTER 7. ROBOTICS

Purpose

Replacing manpower by machinepower for monotonous, accurate, dangerous or heavy work.

Contents

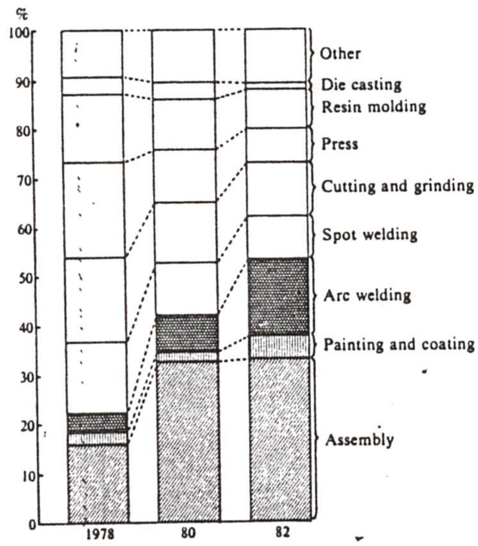
A robot is a machine which executes an action or a number of actions which are programmed. The program gives instructions to the machine by means of a computer. This kind of robot is the most primitive one, and is also called a self working machine. Most of the time however, another feature is added, again by means of a computer namely self control: through sensors (i.e. artificial organs of sense) the machine is able to detect faults or variances in the production and to warn when such fault or variance occurs. The latest development on this field are next to self working and self controlling, the self correcting machines: these are not only able to correct faults and/or variances, but also to correct the programmed process. Integration of these three features leads to a self optimalizing machine and thus to an optimalization of the process.

As most important advantages of the robot in comparison with manpower, the following aspects can be mentioned:

1. a robot can do dirty, dangerous and heavy work;
2. a robot can do monotonous and boring work;
3. a robot can work for more than eight hours a day and in a more accurate way.

The main application of the robot in the construction branch, primarily focused on use within a factory, are shown in figure 15:

Figure 15.
<u>Present applications for industrial robots</u>
(Sources: Japan Industrial Robot Association - JIRA)



Because the description of robotics is primarily focused on use in a factory, it is, with regard to the construction industry, directed to the producing and supplying firms. For activities on the site applications are still being developed, with as one of the latest developments the building of a wall by means of a robot. Because for now the use of robotics on the site is limited to self working machines, this trend is as to the construction industry still at its infancy (only with specialistic work such as tunnelling, maintenance in nuclear plants and working on the sea bottom robots are used).
As soon as self control and self correction can be integrated this trend will break-through for the complete construction industry. The problem however is how to achieve this integration for robots on the site.

Relations with other clusters

As a precondition for the development of this trend the development of specific parts of micro-electronics can be seen. So a strong relation exists between robotics and micro-electronics in general.
Also can a overlap be noticed between robotics and flexible automation: when the programming of a robot is made flexible a robot can be of help within the process of flexible automation; and this also counts for the use of robots as a tool for CAM-systems.

Examples of technological developments

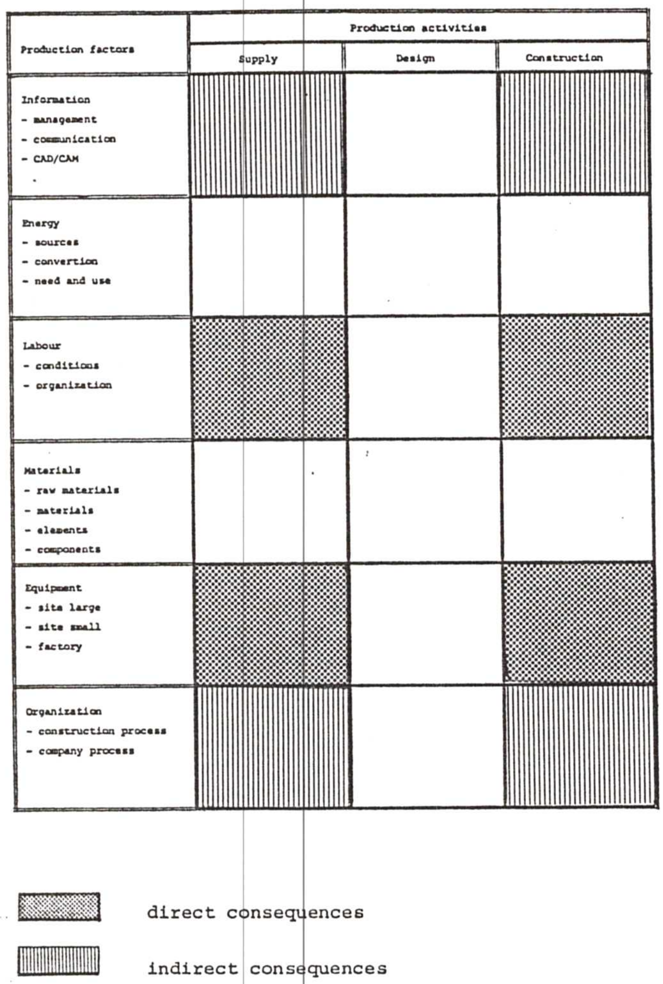
- pick and place robots: these machines can pick an element and put it on another place (e.g. bricklaying robots);
- servo robot: machines which can interrupt, slow down, accelerate or turn a certain activity or action;
- sensory robot: machines which can control a certain process by means of built-in sensors;
- assembly robot: machines which designed to execute assembly activities. It is an integration of the three above mentioned robots;
- single purpose robot: machines which cab be used for one specific job and therefore are uniquely designed.

Examples of effects and using possibilities of these developments

- growing need for more educated and schooled personal;
- improvement of working conditions;
- increase and improvement of production volume.

Figure 16.

Possible changes and consequences as a result of robotics



CLUSTER 8. PROCESS AND ORGANIZATION COORDINATION

Purpose

Organizing the construction process in such a way that every participant fulfills the for him most appropriate job in the most effective way.

Content

The construction process in its conventional form - initiative by the principal, design by the architect and construction by the contractor - exists already for more than hundreds of years: the general principle of the process nowadays looks even still very much alike the principle of the process in the Egyption periode (±2.000 years B.C.). This has been possible because despite all changes, the contents of tasks stayed the same. But on the contrary it is astonishing that in this 20th century the construction process stayed the same.
In this century namely the emphasis did not and does not lie just on social developments or just on economic developments, but on an integration of developments on all fields of society: economy, technology, social and cultural environment and the role of the government. Now the task content of every participant has changed, but because of the unwillingness of some participants the process still is the same.
Furthermore have all participants their own "vocabulary" and their own point of view with regard to constructing: this does not have to be wrong, provided that some kind of coordination exists. But because there is no question of coordination, the problems within the construction process are evident: no coordination between the participants and no adaption of the role of the participants to the changed task-content of these participants.
Beside the occurring problemes of inefficiency, improductivity and unsatisfactory results due to the non co-ordinated process, there are some driving forces that ask for such coordination.

1. In the building branch in general, but in the housing branch in particular the client or consumer wants to play a greater role in the construction process. Because people become better educated, and because their budget has to be divided more carefully, they eant to participate in the decision making process and to express their individual wishes.
2. The strive of contractors to reduce the construction costs without th quality. In this context terms ad industrialization and rationalization fit in, terms which can only meet the needs when an optimal cooperation between the process participants is taken care of.

Coordination is seeked for by standardization or coordinating systems such as dimensional coordination. The change in task-content may result in a threat of for the architect as independent process participant: the changes in society may ask for a more dominant role of the contractor in the design process. The final result has to be that every participant fulfills the for him most appropriate job or task.

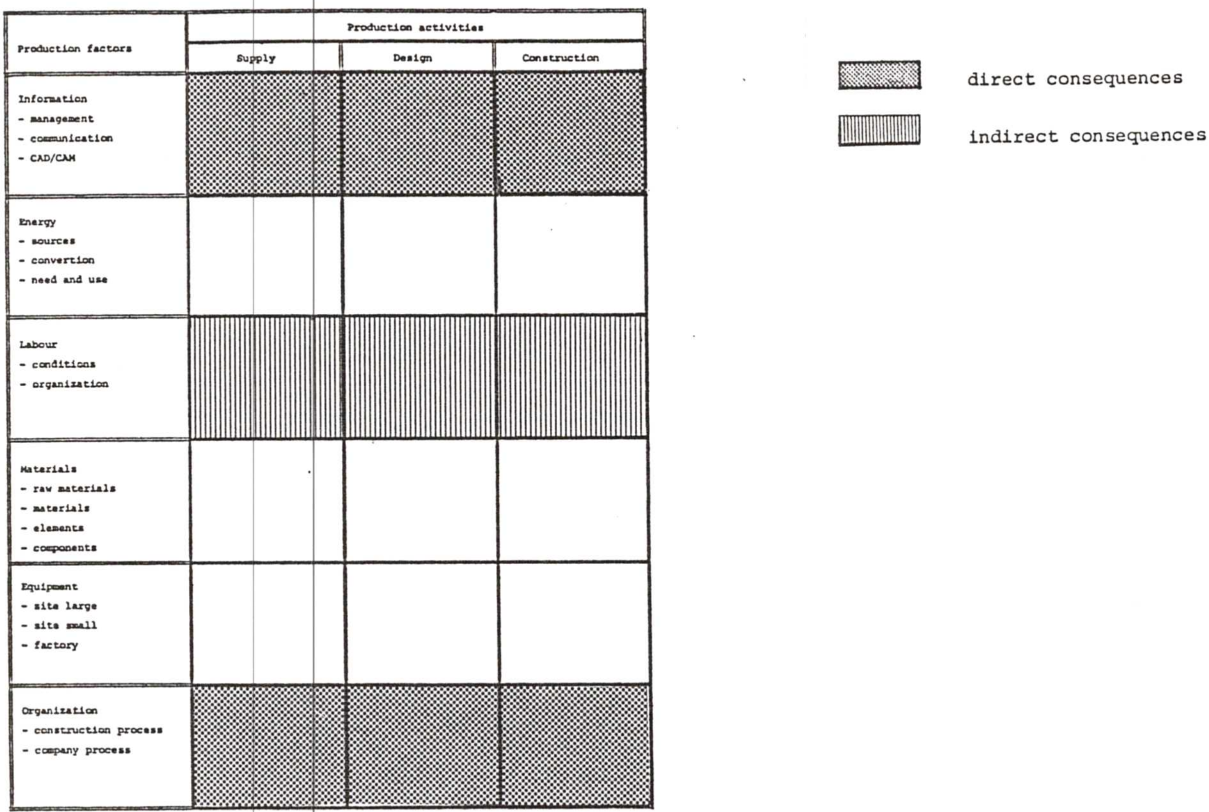
<u>Relations with other clusters</u>

On improved systems of agreements and regulations between the various process participants including an improved circumscription of the task-content of each participant will lead to an improved communication between the participants. Vice versa good communication can be seen as a precondition for process coordination. This communication can be represented by computer-aided-communication, by CAD and CAM-systems and certainly by an integration of computer subsystems.

Also can process coordination be seen as a precondition for this integrating of computer subsystems.
On the other hand process coordination is also a precondition of the clusters, prefabrication of composed components and exchangeable components. When these clusters are well coordinated they can grow out to a construction method.

Figure 17.

<u>Possible changes and consequences as a result of process coordination</u>



<u>Examples of technological developments</u>

- building teams: cooperation of architect, advisors and contractor within a project;
- new forms of tenders;
- specification writing: design method based on specifications as such and not on characteristics or specification of specific materials;
- standardization of construction elements and components;
- dimensional coordination: a design method which uses standarized measures of elements and components;
- centralization of channels and tubes for installations;
- catalogue constructing: constructing with prefabricated standarized elements and components which can be combined into all kind of constructions.

Examples of effects and using possibilities of these developments

- cost reduction;
- another organization of the construction process;
- participation of consumers and clients.

CLUSTER 9. PREFABRICATION OF COMPOSED COMPONENTS

Purpose

Fabrication of large construction components such as facade systems and floor parts in factories, and assemblation of these components on the site.

Contents

Prefabrication of construction components is a technique, which has known an increase in application the last few years, but which might have an even more promising future.
Prefabrication has always had its opponent in the construction branch, although it occured and occurs in various phases ans stadia: firstly prefabrication was limited to the production of construction elements such as bricks, tiles, etc.; later also compared elements sucs as wooden and aluminum door- and windowframes.
As third phase counts the prefabrication of more large scale composed components, such as integrated facade systems and wall-ports but also structural components such as integrated floorparts and foundation elements. This phase the EC in general is in now, while the future opens possibilities for complete prefabricated houses or even prefabricated buildings.
The effect is that the production moves from the site into the factory. This however must not only be seen as the effect, but also as the motive for the increasing prefabrication. This because of the fact that:

1. in the factory more advanced equipment can be used and therefore the productivity can be strongly improved;
2. and therefore also the quality can be strongly improved;
3. in the factory the climatic conditions play no role, with as result that prefabricated components show less variety with regard to quality, measures and surface.

On the other hand the more negative aspects will be the increase in transporting costs and the possible difficulties on the site when a prefabricated component does not fit or is not correct in another way.

Prefabrication has considerable consequences for the equipment on the site, an what is more, for the equipment in the factory, but it also effects the need for transport and infra-structure. Also will the labour activities in the various production locations changes, and the labour activities on the site in particular: the craftsmen will find themselves more and more assembling instead of constructing.

Relations with other clusters

Bringing back a great part of the production from the site to the factory has a lot of technical consequences, and so prefabrication can be related with clusters of developments as flexible automation, computer-aide-manufacturing and robotica, but the relation which is less self-evident but certainly not less important is that with process coordination: when the production location changes from site to factory, the coordination between the various participants has to change too. Also can prefabrication of easy to exchange and easy to replace components be seen as an opportunity for anticipating to the continuous changing market needs.

Examples of technological developments

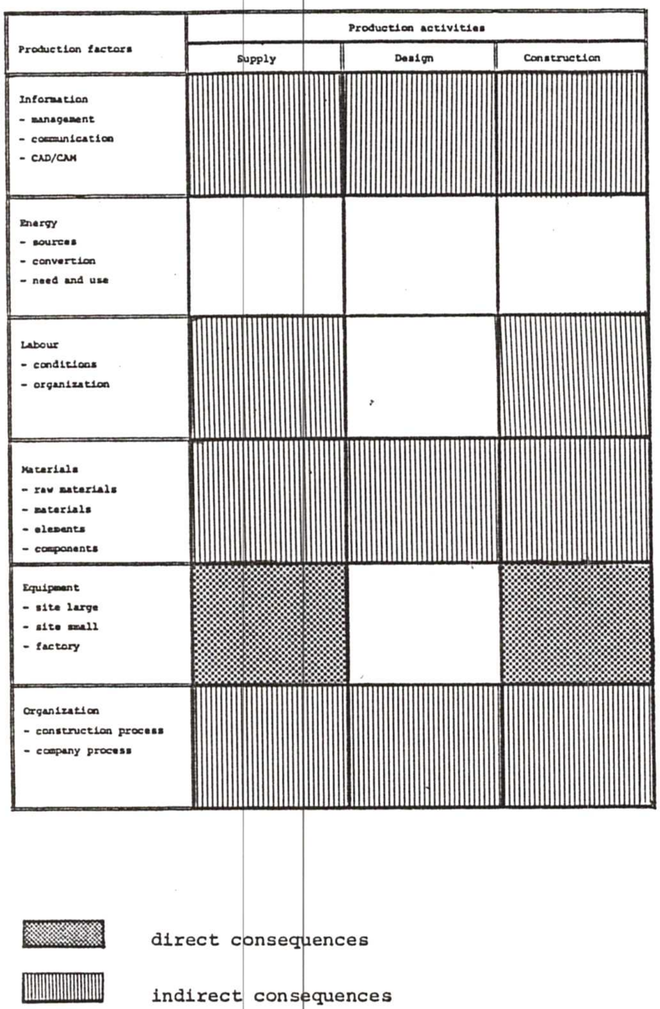
- equipment in the factory;
- prefabricated roofsystems, wallsystems, facadesystems, etc.;
- new types of joinings and fittings;
- mobile homes.

Examples of effects and using possibilities of these developments

- change in labour-task of the craftsmen on the site

Figure 18.

Possible changes and consequences as a result of prefabrication of composed components



CLUSTER 10. EXCHANGEABLE COMPONENTS

Purpose

Producting structural as well as infill elements and components which can easily be replaced and exchanged on the site.

Contents

The demographic and socio-cultural conditions have changed drastically the last decade: people have become more and more individualistic, they have got better and more educated, the number of divorces has increased enormously, less children have been borne etcetera.
This resulted in a change in needs and wishes of the people, also with regard to the construction market in general, and the housing markt in particular.
Anticipating to these changes has appeared to be very difficult for many institutions and organizations and also for the construction branch: qualitative adaptation o of the supply side to the demand site has still not been reached fully by just one of the EC-member states.
This aspect, reinforced by the growing need for renovation and maintenance of constructions and the growing need for adaptation of existing constructions to new needs and wishes, is the motivation for the introduction of exchangeable components.
The use of exchangeable components is not only directed at structural parts of construction, but also to the infill. It asks some degree of standardization of joinings, and fillings, so that the components mentioned above can easily be exchanged and replaced. It will be clear that agreements have to be made about this standardization between the various process partners the designs has to alter its way of design, the supplier has to adapt its production to the standarized joinings, while the contractor has to adapt its capacity both equipment and labour-capacity, to the change in way of constructing.

Relations with other clusters

Because exchangeable components can be used not only in new constructions but as said, also within already existing constructions, the use of it will result in little-scale tools and equipment and what is also important in a lot of little scale demolition techniques. So the relation with the tools and equipment cluster is obvious.
The relation between exchangeable components prefabrication of composed components, and prefabrication will need no further explanation.
When the use of exchangeable components sets trough an when a certain coordination between the participants of the construction process takes place, one could even speak of a new construction method.

Examples of technological developments

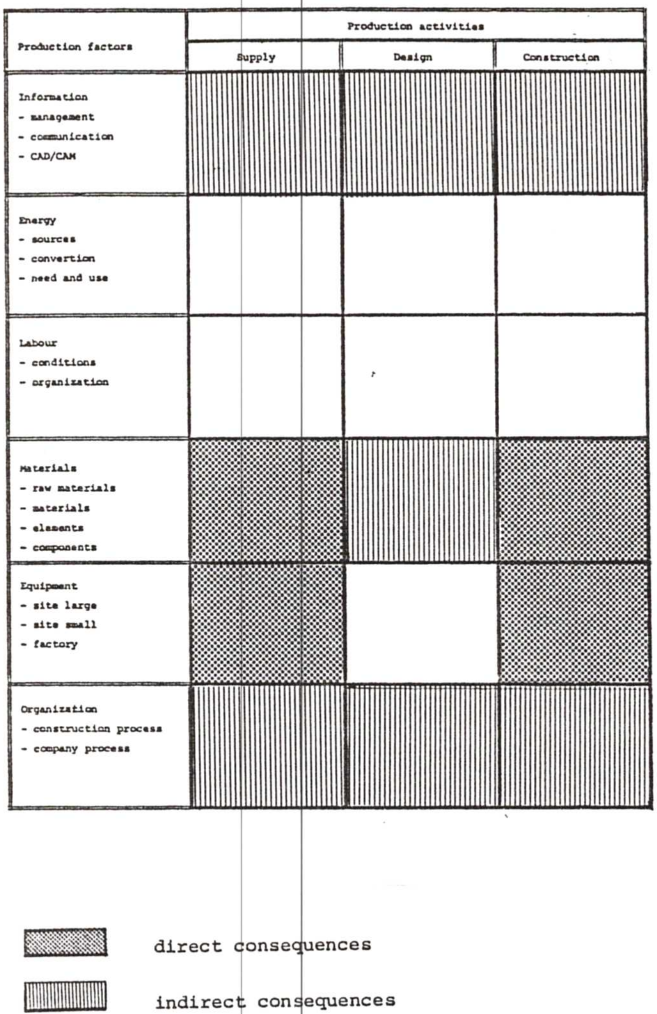
- renovation techniques;
- demolition techniques;
- separation between structure and infill;
- mobile separating walls.

Examples of effects and using possibilities of these developments

- open building method: separation of main-structure and infill which exists out of exchangeable and replaceable components to increase the flexibility of constructions;
- flexibility;
- multi-functionality.

Figure 19.

Possible changes and consequences as a result of exchangeable components



CLUSTER 11. MATERIAL DEVELOPMENTS

Purpose

Developing new materials and new applications for current materials.

Contents

For the near future a real explosion of new materials in the construction branch is expected.
Innovations on this field can be divided into two main groups:

1. development of new materials as such. Research for this item is focused at:
   - single materials (e.g. synthetic materials, steal encampment);
   - composite materials (e.g. fibre reinforced concrete, foamed products with an iron kern).
2. new applications. For example the expansion of appropriate use of plastics within the construction branch.

Most of the time developments within the field of materials are the result of changes in the society in general and in the market demand in particular: cost reduction, energy saving, low cost housing programs will always find material research as a part of their program.

Relations with other cluster

Materials are as already said most of the time the result of changes in the market demand. These changes must technically seen be possible but also materials technically seen.
For example for the introduction of exchangeable components specific fabrication techniques have to be developed, but when no materials fit with there techniques the introduction of exchangeable components will be impossible.

In this light material developments must be seen as a precondition for flexible automation, prefabrication of composed components and exchangeable components.
The relation with energy conservation will be clear too.

Examples of technological developments

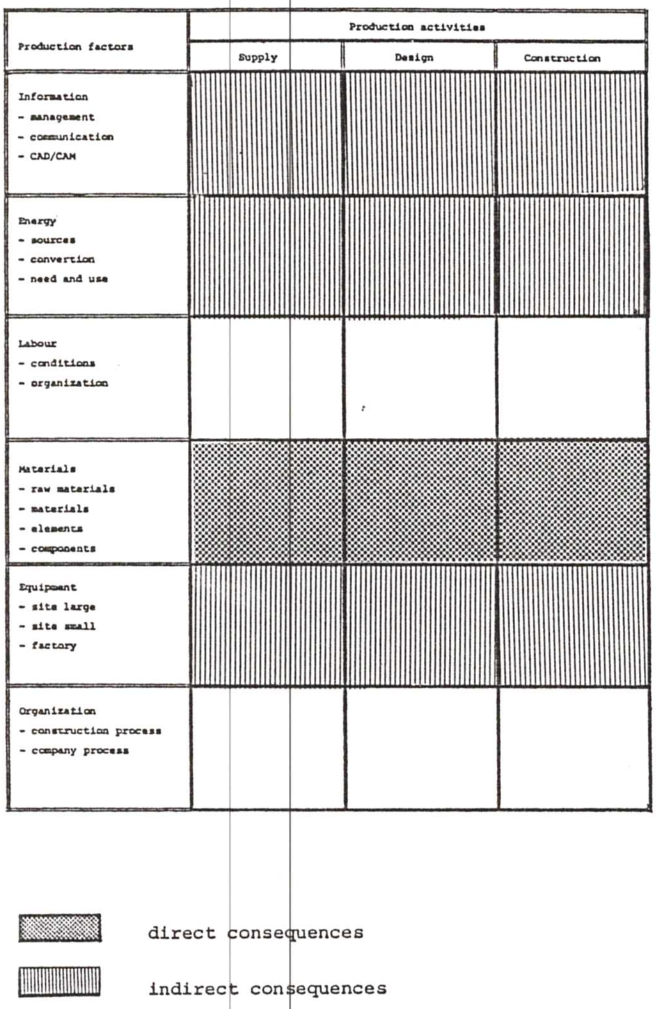
- new types of high quality concrete;
- fibre reinforced concrete;
- new types of high quality cement;
- new fillers for concrete;
- new types of glue and glueing techniques;
- lightweight metals;
- materials which are not harmfull for the health and safety or organism;
- new types of paint and painting techniques;
- sandwich materials;
- foamed elements;
- synthetic materials in the installation sector;
- "vandalism proof" materials.

Examples of effects and using possibilities of these developments

- cost reduction;
- energy conservation;
- less labour intensive production;
- noiseless production;
- improvement of health and safety.

Figure 20.

Possible changes and consequences as a result of material developments



CLUSTER 12. CONSTRUCTION SYSTEMS AND METHODS

<u>Purpose</u>

Developing new ways to realize constructions or part of construction through a new way of building.

<u>Contents</u>

After the second world war a real hausse could be seen with regard to industrialization and the here with connected construction systems and methods. Although the character changed with the time (in the sixties mass fabrication, in the seventies variation and differentiation) the search for improved and better systems and methods did not stop. And this reach has still not stopped. There are now three main stimuli further development, namely:

1. cost reduction and quality improvement. Because of the smaller budget of clients throughout the EC; their wishes get a more and more important place within the construction process, and so cost reduction as well as quality improvement get but certainly will get a lot of attention;
2. renovation and maintenance. Parallel to the decline in the new building program a growth takes place within the renovation and maintenance sector. New techniques as well as new systems and methods are needed to meet this new need;
3. partly because of the smaller budget, partly because of the growth in leisure time, the do-it-yourself activities show a certain development. These do-it-yourself activity give cause to the development of new systems and methods (e.g. building packages, infill etcetera).

The new systems and methods will not be restricted to technical aspects, but changes have to be made also in the field of regulations, codes and arrangements, because of the drastical change a new method brings about.

Relations with other clusters

New ways of building and constructing ask a lot of coordination between the process participants because they have to change the whole content of the construction process within a project: a strong relation can be established with the process coordination. Indirectly, CAD systems can be of great help for developing new systems and methods, while an integration of prefabrication and process coordination may result into new systems and methods.

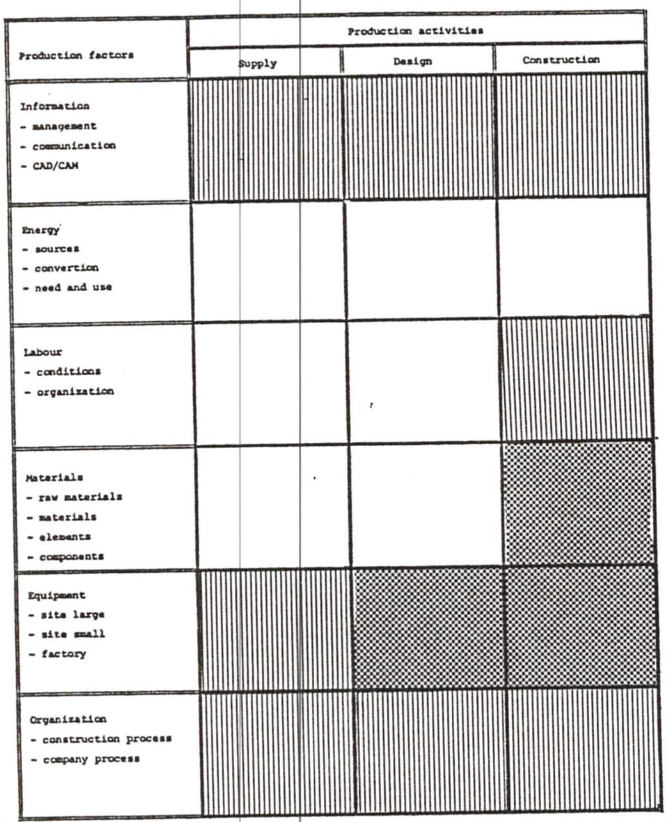
Examples of technological developments

- wooden formworks;
- aluminimum structures;
- steel skeletons and structures within the housing industry;
- building packages.

Examples of effects and using possibilities of these developments

- need for new equipment;
- need for new materials;
- more appropriate answer for renovation and maintenance.

Figure 21.
Possible changes and consequences as a result of construction systems and methods



direct consequences

indirect consequences

CLUSTER 13. CONSTRUCTION TOOLS AND EQUIPMENTS

Purpose

Developing new aids for the craftsmen on the site as well as in the factory.

Contents

Throughout the years the instruments used by craftsmen in the construction branch have changed drastically. Not that the conventional tools such as a hammer and a saw are not used anymore, but a great deal of substitutes are introduced. Developments on this field must be seen as the result of driving forces: a change in technology as well as a change in the demand of the construction branch may need a new kind of aid or instrument.
Nowadays this becomes clear in the changing volume of the tools and the equipment: because of the more and more little scale projects and because of the improved flexibility equipment becomes more little scale.
On the other hand tools are becoming more and more professional because of the technological developments on this field (pneumatic and automatic tolls), but also because of the growing market of do-it-yourself activities.
Although developments on this field are primarily directed at the construction and supplying firms, the design forms should be aware of these developments, because with a thorough knowledge they can make the appropriate use of this in their designs.

Relations with other clusters

When changes take place in the way clements or components are supplied to the site, the construction tools and equipments on the site as well as in the factory will undergo changes.

So both prefabrication of composed components and exchangeable components, but also production processes as flexible automation, computer aided manufacturing yes or no supported by robots will influence this cluster of developments.

<u>Examples of technological developments</u>

- manipulators: instruments which enlarge human force;
- pneumatic tools on the site;
- conveyorbelts on the site;
- automatizated equipment;
- wireless communication.

<u>Examples of using possibilities and effects of these developments</u>

- change in taks content for the craftsmen;
- growth in do-it-yourself activities;
- improvement in ergonomics.

Figure 22.

Possible changes and consequences as a result of construction tools and equipments

Production factors	Production activities		
	Supply	Design	Construction
Information - management - communication - CAD/CAM			
Energy - sources - convertion - need and use			
Labour - conditions - organization			
Materials - raw materials - materials - elements - components			
Equipment - site large - site small - factory			
Organization - construction process - company process			

direct consequences

indirect consequences

CLUSTER 14. HEALTH AND SAFETY

Purpose

Providing better health and safety conditions for craftsmen, both in the factory as well as on the site.

Contents

The health and safety problem in the construction industry is just a recent one: fifteen years ago it could hardly been found in the construction, vocabulary. In addition to the humanitarian reason. for preventing personal injury and loss of life, increased attention to safety and health is also essential to the long term economic health of the construction industry: costs related to construction accidents are borne by the principal, directly or indirectly.
The direct result of an accident is obvious, but the indirect results, which will always cost money, can for example be:

- loss of productivity;
- disrupted schedules;
- administrative time for investigations and reports;
- clear up and repair;
- equipment damage;
- adverse publicity etcetera.

Although principals have a direct economic stake in the safety performance of their contractors - accident costs are an expense to the contractor an dare possed on, one way or another, to the client - they should also reinforce their moral commitants to provide a safe work environment.
An effective construction safety program will therefore beside better working conditions result in lower job costs.
The cost of construction health and safety programs are not easily to define, but usually they amount to about 2,5% of direct labour costs.

These program includes:

- safety meetings;
- inspection of tools and equipment;
- site inspection;
- use of personal protective equipment;
- health tests and control, etcetera.

By showing more concern for construction safety, not only injuries can be reduced as well as losses of life, but also a lot of money, needlessly washed by construction accidents.

Relations with other clusters

The cluster of developments on the field of health and safety is a quite separate one: the only obvious relation that can be established is that with construction tools and equipment: as will be clear now this is one of the important parts of the health and safety programs.

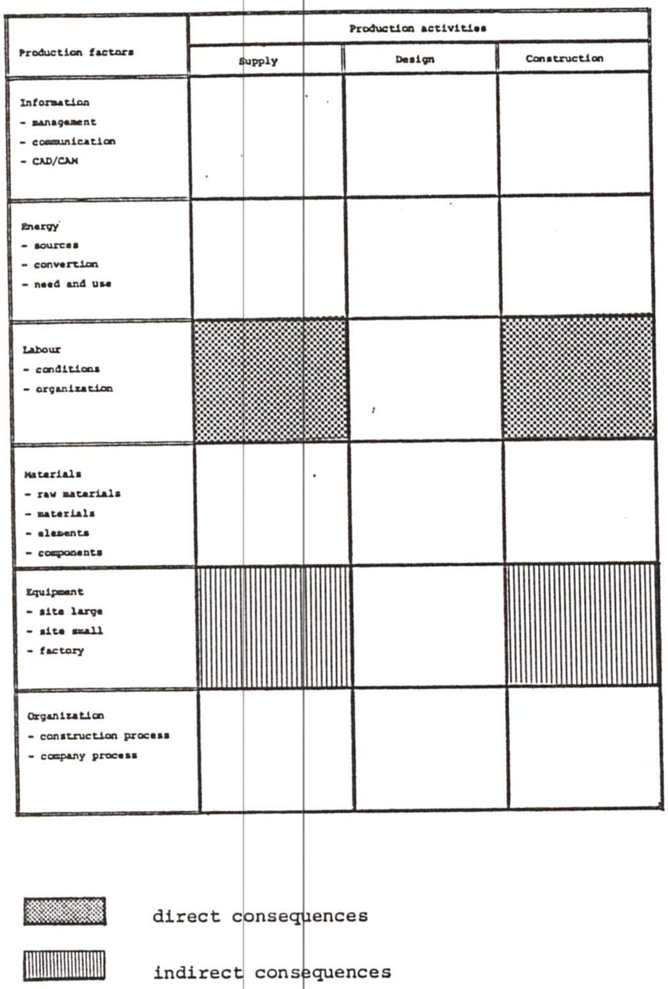
Examples of technological developments

Examples of effects and using possibilities of these developments

- health and safety programs;
- productivity improvement;
- cost reduction.

Figure 23.

Possible changes and consequences as a result of health and safety



CLUSTER 15. ENERGY CONSERVATION

Purpose

Lowering the energy consumption for the production and during the use of constructions.

Contents

Since the first oil crisis in 1972 the item of energy conservation has been on the research and development program of all EC-member states.
A part of these programs was directed at the construction industry which resulted in special attention for this subject. Because of the growing energy prices and because of the fear for a shortage of energy sources in the future the attention is still fixed at this subject.
Three different fields of research can be distinguished:

1. research for more energy saving materials, in the sue as well as in the production;
2. diversification: research for alternative energy sources;
3. energy management: an energy planning and control method for during the use of a construction.

Developments on this subject can not just be introduced and applicated by process participants, but a great influence is executed by the society: they determine whether to use of not to use a specific material, and if they want nuclear energy stations or not.
This external influence can be noticed with more clusters, but with this cluster in particular.
Furthermore it should be mentioned that energy conservation is oftenly seen as one of the most important driving forces, and in this case market-pull factors for innovations in the construction industry.

Relations with other clusters

Energy conservation is a quite single and unique cluster of developments. Links can be drawn to the material developments and to the developments within the field of computer systems, but these relations are just indirect.

Examples of technological developments

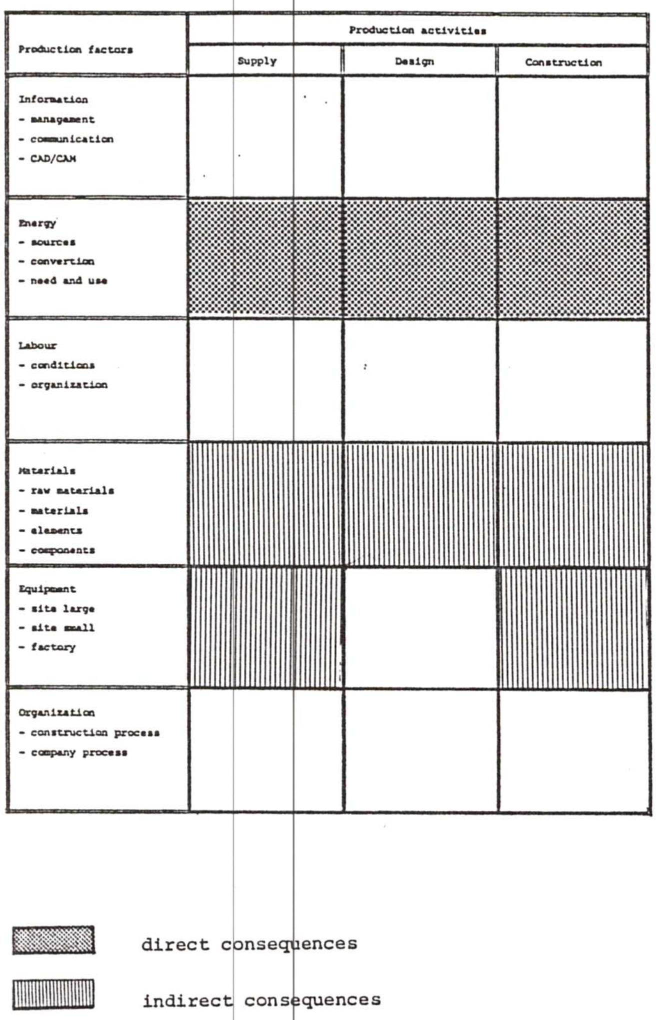
- new isolating materials;
- energy conscious production methods;
- new fuels;
- high return boiler;
- heating pump;
- solar energy;
- wind energy;
- bio energy;
- nuclear power (nuclear fision and unclear fusion).

Examples of effects and using possibilities of these developments

- energy conscious design;
- energy conscious production;
- integration of energy conservation and other characteristics within one component (e.g. foamed materials which are hight, structural and energy saving clements).

Figure 24.

Possible changes and consequences as a result of energy conservation



CLUSTER 16. OTHER DEVELOPMENTS

In the construction industry in general but in the civil engineering industry in particular a lot of technological changes are single and unique developments. The purpose of the civil engineering branch can be summarized as:

- protecting the land against the water;
- construction of harbours and searoutes (channels etc.);
- construction, use and maintenance of the roads;
- construction of artificial works such as viaducts, sea tunnels etc.

The content of technological developments within these purposes can best be shown by means of the examples of technological developments:

- nylon and plastic folies for the protection of roads, barks and sea bottoms;
- new kind or roadsurfaces e.g. with synthetic grinds;
- painting and conservation techniques for protection of constructions and construction surfaces;
- sensors for registrating the changes within the waterlevel;
- chemicals against waterpollution;
- ecotechnique: techniques to clear polluted earth.

One important single technological change is the development of recycling: old constructions are demolished, grindled and used against as filler material for concrete, asphalt etcetera.
This development gets a lot of attention because milieu activities as well as the general opinion stives more and more for an effective and sparesome use of materials.