KNOWLEDGE ASPECTS OF CONSTRUCTION PLANNING REDESIGN

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Abstract
Traditionally seen a construction company starts working on a project the moment the design phase is finished and the specifications of the project are defined. At this point in the building process the company has to decide, in a rather short period of time, how, with what and with whom they are going to produce the specified design. Also traditionally, these actions of the construction company are regarded to be rather banal and they carry with them the image to prepare a production process in which a lot of errors occur. Earlier research indicated a different approach to this planning process to be successful. This design approach however asks for new theoretical concepts and new working methods.

In this paper we will present the temporary results of an ongoing research project in which we will develop a theoretical concept of designing construction processes and a design tool for the planning engineer with which it becomes easier to monitor internal cohesion of the construction plan. The theoretical concept contains a description of the results of the design process. This so called production plan consists of a set of plans and a set of scenarios. Each plan contains all collected information on one single production aspect (e.g. labour and safety, timetables, measurement information). Each scenario or scheme contains all information concerning the production of a single part of the building (e.g. foundations, glazing, inner walls). The tool to be developed will be a knowledge based system with which knowledge can be managed.

The article is concluded with a description of the expected results of our research.

Keywords: planning; construction plan; knowledge based system.

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1 CONSTRUCTION PLANNING

Within the world of construction exists a growing realization that the planning (or work preparation) phase holds a crucial position in the building process. During this phase the construction process of a building is prepared. On the basis of the contract documents (specifications, drawings, tender budgets) details are given of how, when, and in what way construction will take place. During construction the building is realised to the extent that the requirements of the contract documents are met and with that the needs, expectation, and conditions of the party that commissioned the building and/or the potential users.

There still is confusion about the activities that fall within the work preparation and the output of this phase. In a publication of the Dutch Building Research Foundation, work preparation is briefly defined as: “The technical elaboration of the specification plan, allowing construction to be directed and checked” [Tijhuis, Maas en Spekkink, 92].

However, if we turn to more descriptive literature regarding work preparation, something seems missing from the definitions and descriptions listed above. Poortman writes: “It is clear that a planning engineer has to take different views while drawing up the plans: sometimes he has to consider the process as a collection of team tasks, then it becomes a collection of work methods, only to turn into a series of core tasks” [Poortman, 1994]. Huttinga uses the term `construction considerations'. All considerations have to lead to a decision, but nevertheless have to be weighed. Unfortunately, the weighing criteria are somewhat opaque: should the price determine everything? Or how about the construction time? What about social factors? Maybe high quality should determine it all. “As long as it is clear which consideration weighs the most, it is not that hard to take decisions. But decisions often have unintended and unexpected side-effects. Moreover, considerations are interconnected” [Huttinga, 1986].

Finally, Sjaarda describes a model of work preparation as a black box with information, input, and output. As a result of research carried out at Ballast Nedam, an inventory was made of all the activities that occurred during work preparation, which were then placed in a model and linked to each other. The result is a representation of work preparation as a problem-solving, design process [Sjaarda, 1992].

We feel this view of work preparation, which looks beyond guiding and monitoring or planning and elaborating, encourages a better understanding of work preparation: it is a view that is based on the work preparation process with a partially design-oriented character.

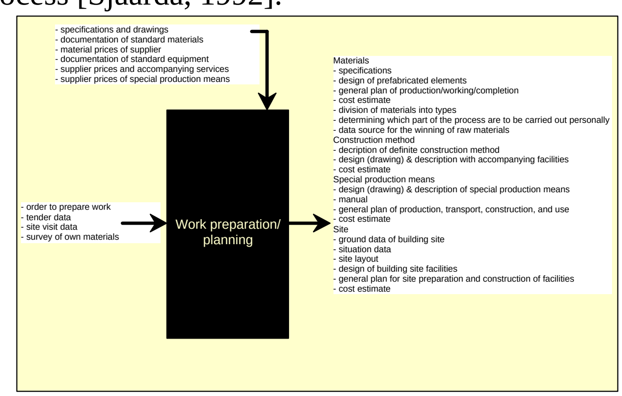

Figure 1 work preparation blackbox [Sjaarda, 1992]

2 DESIGNING CONSTRUCTION PROCESSES

To gain insight into what really happens during this design process (what is going on inside the head of the designer?), earlier Ph.D. research looked at what information the designer uses, in what way he processes it, and in which order this happens. This research provides insight into the first part of the design process in particular: the analysis phase. To this purpose a method was used called protocol analysis, in which experts think aloud while dealing with design problems. “We will first look at the situation...So, this is the situation. It is accessible on two sides, there are important large roads in the neighbourhood so supplies and transport should be no problem...” [Mr Freyen, in: Stockings, 1996].

Through this precise analysis much has become clear about part of the design process. By means of this Stockings found an adapted division of activities into a number of phases:

- Analysis Initially, the designer will want to know what kind of project is involved and what information is available. The analysis process leads to a three-dimensional, mental image of the project and to a number of (automatic) consequences (these are mainly restricted to a fairly general level, while details are usually added later). The result of the analysis can be described as a fairly rich thought structure related to the final result in connection with a set of consequences, boundary conditions, and restrictions.
- Synthesis Synthesizing can be viewed as bringing together chains of activities with the corresponding available capacity (materials, equipment, and labour). The mental model built up in the analysis phase is given more and more details, where continuous interaction takes place between these details and the mental model. This way the model can be transformed.
- Evaluation Evaluation basically occurs continuously during the design process. In the evaluation phase the internal consistency is protected and continual check are done to see whether the design meets external boundary conditions and restrictions (that no doubt were not all known at the beginning of the process) [Stockings, 95].

The construction process consists of fitting out the building site, realising the building, and dismantling the building site [Poortman, 1994]. If we consider the building process as a number of consecutive phases, then we can largely place the activities that falls under the design of the construction during the price-making phase and the work preparation phase. The moment the information concerning a new project becomes known to an executive building company, nothing is known about the project. The information is set down in the shape of specifications. The enclosed request to the company, for example, is to make a tender, i.e. how much will it cost to realise the building project described in the specifications? At that moment a number of far-reaching decisions have to be taken by some planning engineers. They have to make a choice whether the most important bottleneck (which applies to this specific project, at this specific

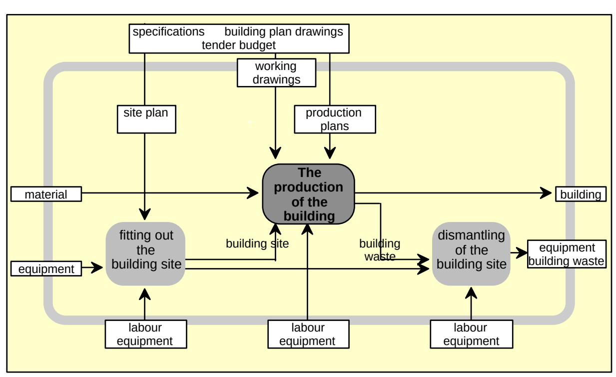

Figure 2 Construction plan [Poortman, ‘94]

time, and for that specific company) is the supply of building materials, for example, or whether it lies in the repetition of certain activities. In the first case a choice will be made for a site with optimal accessibility with cranes positioned in a way that allows trucks to quickly make their deliveries. In the second case, the cranes will be positioned in a spot where there is a clear overview of the framework used allowing for optimal transport in the project. It is clear that these two approaches will not always lead to a similar construction process.

The plan designed by the process designer on the basis of the specifications and the drawings, of the site data, and of the available capacity is known as the design of the construction. The design is a complicated, iterative process in which the building problem and the available capacity are analyzed, construction variants are generated and selected, and construction aspects are set down in a construction plan.

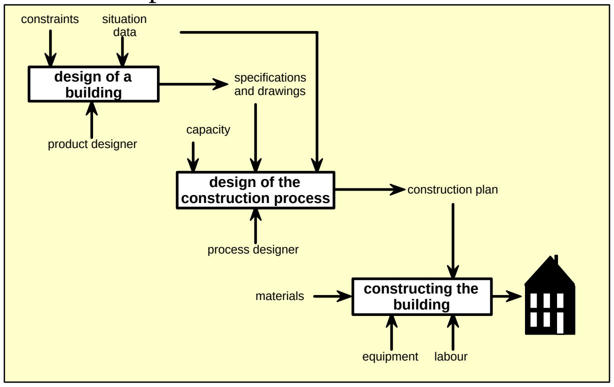

Figure 3 planning in phases

During the building construction a certain productivity is reached that deviates from the ideal productivity. By ideal productivity we mean the relation between the input (equipment, materials, money, etc.) and the output (building) as would arise if no interference occurred. In practice there always are interruptions (e.g. delays as a result of weather conditions) or construction considerations are not chosen optimally (e.g. incorrectly selected work methods) [Alarcón and Ashley, 1995].

The objective of the construction design (and of the developing of this plan) can therefore be summarized as the choice of and balancing of all the available means, as well as the avoidance of interruptions by keeping tabs on the sources of these interruptions (prior to and during the construction process). It is of course impossible to keep track of all possible sources of interference, and moreover it is clear that interruptions can be related to each other. The latter makes it necessary to optimize solutions to prevent interruptions. What does a plan of the construction process need to achieve this objective? The construction plan has to leave no doubt as to its achievability, or its constructability. The aspect of constructability can be defined as: `the optimum use of construction knowledge and experience in planning, engineering, procurement and field operations to achieve overall project objectives' [Hanlon and Sanvido, 1988]. So, it is about the capacity to realize things and to apply construction knowledge. Initially, this means that the plan must be demonstrably constructible technically within the boundary conditions given. Technical constructability alone, however, is not enough. The party commissioning a building often has a whole list of vague problems besides all sorts of clear wishes and requirements. The client not only wants to see solutions to clearly indicated requirements but also solutions for problems less clearly expressed. A third aspect to constructability concerns covering the risks for the building company. Earlier on we already referred to the fact that guarantees are becoming increasingly important. Among other things this means that liabilities and the risks related to this are increasing too. Since the complete avoidance of risks is not an option due to the costs and time involved, an important aim of the plan for the builder is to deal with the risks he can run as well as possible. The construction plan has to meet three requirements to achieve the design objective (choosing and optimally balancing all available means and preventing interruptions by keeping tabs on the sources of these interruptions):

- The building has to be constructible within the boundary conditions given.
- The party commissioning a building should have its questions and problems solved by the plan.
- The risks have to be managed properly.

Construction plan

In tandem with the research of Stockings into how things work in practice, a concept based on theory has been being developed. It arose from the ideas referred to earlier concerning the construction concept and the construction plan. This development is more based on a `new' method for the design of construction than on what happens in today's reality. However, it certainly has a practical orientation and therefore is aimed at a result. The final result is called the construction plan and consists of a number of documents that mostly are directly linked to the plan used in practice.

Here, a largely comparable structure is used as in the research of Stockings: analysis, synthesis, and detailing. Within this framework the end products for each phase are described:

- An analysis of jobs, construction, installations, situation, and the available capacity.
- An outline of the construction: a collection of general solutions. In the outline answers are provided to questions like how are we going to build this project, how are the building components going to be manufactured, what composition are they going to have, and how are they going to be connected?
- A construction plan or a set of constituent plans and a set of schemes. In a constituent plan the description is given of a specific production aspect (similar activities) combined for all building components (within one project) for the entire project [Maas, 1994]. In a scheme all information concerning all relevant aspects of one specific building component is collected.

Though one principally needs to consider which constituent plans are relevant for each project, there is a group of constituent plans that generally apply:

- **Measurement control plans** A document in which details are given of the accuracy of measurements necessary for the activities to be carried out, why this is the case, and in what way the accuracy of measurements has to be checked. The most important objective of measurement control is the limitation or minimalisation of the negative consequences of measurement deviations for the functioning of the building, the costs, and the labour conditions.
- **Transport plans** A transport plan consists of a collection of documents in which the organisation is given of the material and equipment flows to and from the building site during the production phase.
- **Labour management plans** In these plans measures are described that need to be taken on the site to arrange a safe and healthy work situation. The aim is to prevent unnecessary improvisation, accidents, and illness by creating obligations regarding safety of the building site and give pointers to the people involved.
- **Logistic plans** In this set of plans the organisation is given of how to get the right materials of the right quality, in the right quantity, at the right time, to the right place.

Orders and calls are arranged in the plans, in which the point of departure is the processing of the materials according to the team task schemes.

- **Site plans** With a site plan all site aspects are controlled during the construction phase with an aim to encourage safety and the work climate and to achieve the most efficient production with the lowest costs for transport and storage. A site plan is not static; it has to be altered for each of the consecutive phases .
- **Time management plans** These are plans for the management of the production factor time during the construction process; in the first instance the total construction time has to be minimalised.
- **Cost management plans** Within these plans the costs of the production factors materials, equipment, and labour are recorded and checked. On the basis of the tender budget a large part of the other plans are established [Maas & Vissers, 94].

Though a schematic description of the contents of the most frequently occurring constituent plans is given here, the contents of a plan or scheme is determined per project. Using the above descriptions and the circumstances of the project, a project-bound plan definition is made. A scheme is made of a number of building components (the most important

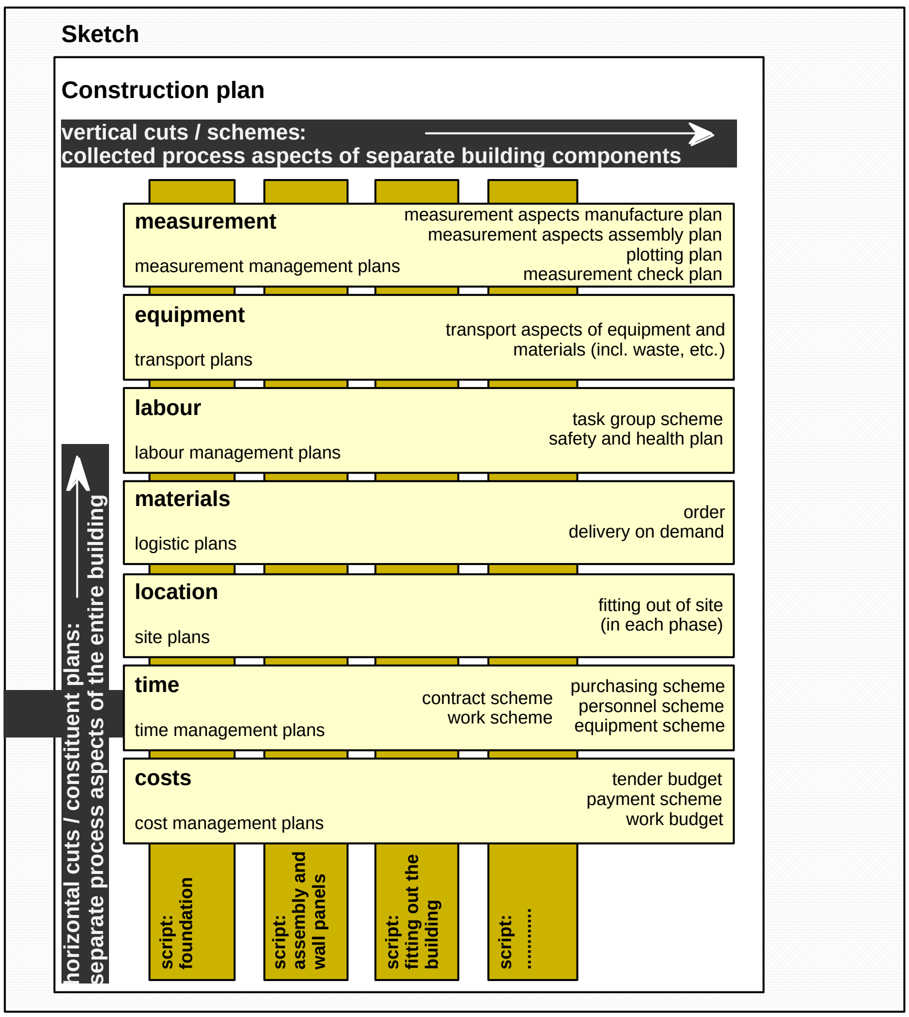

Figure 4 detailed sketch in constituent plans and schemes bottlenecks). Schemes are made to provide the works foreman with all the related information regarding all construction aspects while making a building component. That is the moment at which the works foreman immediately has to link the delivery of materials to team tasks and the use of equipment, and the fitting out of the workplace is linked to the order of assembly of related building components. A scheme gives fine details on the way something has to be made: all production aspects are described for one building component. The result of this design process, a construction plan, therefore consists of a set of constituent plans and schemes [Maas, Vastert, and Leijten, 1996].

3 MONITORING COHESION

In the previous paragraph we explained the objective of what we called "the construction design". This objective can be conceived as the external constraints of the construction plan. To achieve this the plan must meet certain requirements like e.g. a balanced development or an internal cohesion.

This not only means the various production aspects (each is developed and described in a separate plan) must meet certain specific standards, it also means the complete design must meet certain standards. To achieve this the internal cohesion between the various constituent plans must be clearly stated.

Actually, monitoring internal cohesion between various plans is an essential part of design. For a designer the design task often consists of a set of ill defined constraints and conditions out of which a solution has to be synthesised. The constraints and conditions are not only complementary but can also independent from each other or even be conflicting. Therefor an important part of design is the process of constantly comparing and guarding the coherence between the invented solutions.

On the one hand this cohesion of the construction plan is indicated by the existence of the schemes. In each scheme all information concerning all relevant aspects of one specific building component is collected. On the other hand schemes are only made for a small number of building components. Also a scheme is only drawn up after the constituent plans are finished.

Earlier in this article we described a model of the design process as being a phased process. Although the final design can only be composed out of the separated design decisions if all these decisions are made (a synthesising process), the internal cohesion between these separated aspects has to be monitored closely during the complete design process. Optimal monitoring appears to be crucial but complicated. The process of guarding coherence is conceived to be a knowledge problem. Neither is there a deficiency of knowledge, nor is there a gap in the planners knowledge. Instead it is a matter of managing knowledge. This means the necessary knowledge is not recognised by the right person, the knowledge is not at the right place at the right moment or there is just to much information to be dealt with.

Knowledge Aspects

With Lucardie we define knowledge as the ability to match objects to object types. Objects can be conceived as data in general, as plain information. These data only become useful the moment they meet certain requirements. These requirements are described in so called object types. Matching objects with the object types is mostly complicated because the constraints written down are rarely complete. Therefor the person who is trying to match has to deal with some kind of uncertainty, with fuzziness [Lucardie, 1994], [Lucardie, L., J. de Gelder en G. Visser, 1995].

When monitoring internal cohesion of a design, the designer collects a lot of data, of plain information. Also a lot of constraints are already, or become familiar to him (e.g. maximum building costs, national building regulations). These constraints act like the object types to the designer.

Earlier research stated that the knowledge and information flows between the various participants during the different phases of the building process were the highest during the planning phase. This indicates once more the complexity of the monitoring process [Huijbregts, 1996]

5 CONCLUSIONS AND FURTHER RESEARCH

A year ago we started a major research project to further develop the above described theory. The goal of this research is to develop work methods for designing construction plans and tools to support the design process. These methods and tools must be usable in daily practice and therefor not only being based on academic views.

In this research we shall focus on keeping tabs on relations between the constituent plans. Earlier in this article the objective of the design of the construction was dealt with. The aim of the design (technical constructability, providing answers to questions and problems of the commissioning party, and risk management) can be viewed as the external requirements made of the design. This not only means that the various construction aspects, which each are described in a separate plan, have to meet the requirements that apply to a specific aspect, but that also apply to the entire design. For this to be the case the relations between the constituent plans have to be clear and unambiguous. Monitoring this cohesion is a complicated process. All aspects have to checked continuously and decisions have to be made all the time about which arguments are decisive for the preparation of part of the construction process. The management of this cohesion is a very intensive process, in which a large amount of knowledge, a broad overview, and proper communication is necessary. Management of knowledge is the key word here.

In this research we are working in collaboration with TNO Building and Hurks Building Company. By means of a research on a longitudinal case study insight is gained into the requirements made of the end product of the work preparation. With this a work method can be set up that is a better way to obtain the desired product in a coherent fashion. This research will go on for another three years and will result in a improved model of the design process of the construction phase, a working method for the designer and a demo version of a knowledge based system with which the designer can better manage information flows and general knowledge.

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