

# A DECISION SUPPORT SYSTEM FOR A CRANE PLAN AS PART OF A GENERIC CONSTRUCTION PLAN

**Frans van Gassel and Wim Schaefer**

*Eindhoven University of Technology, Faculty of Architecture,  
Building and Planning*

*Department of Construction Engineering and Management,  
Eindhoven, The Netherlands*

*f.j.m.v.gassel@bwk.tue.nl and w.f.schaefer@bwk.tue.nl*

**Abstract:** After a building has been designed the construction process necessary to make the building also has to be designed. The theoretical framework of the “Construction Plan” has been adapted to our research project in order to structure the design of this process. The crane plan exists in this framework as an important sub-plan. A crane is a very important piece of equipment on the construction site. It can influence production time, costs, working conditions and the quality of the product. The choice of a suitable crane is essential in designing the construction process. We have developed a crane plan as a decision support tool that fits into the generic framework of the Construction Plan, using a knowledge base and a database for cranes. This not only supports the choice of a crane necessary for the job, but also takes account of relationships between construction sub-plans and specific scenarios within the whole context of the construction process. The crane plan has been tested by making use of an expert panel and by applying for the reconstruction of a recently finished construction process.

**Keywords:** Crane Plan, Construction Plan, Decision Support Systems.

## 1. INTRODUCTION

Construction activities complete the building to the extent that the requirements of the contract documents are met as well as the needs, expectations, and conditions of the party that commissioned the building and its potential users. Before those activities can start on site, a rather complex production process of on-site activities has to be developed and a generic plan for the construction designed.

This paper describes a tool for designing one part of this generic plan. Developing tools for designing production processes for buildings on site is one of the research topics of the Construction Engineering and Management Department at Eindhoven University of Technology. This research group has developed a theoretical framework for an integrated approach to the aforementioned generic construction plan. Within the boundaries of this theoretical framework, a decision support tool for designing the crane plan has been developed [8]. Use of this crane planner is limited to the construction processes for (non-) residential buildings, where telescopic, crawler and tower cranes are used. We describe the incorporation of the crane planner into the “Construction Plan”. A prototype of this decision support tool has been built as a software package. The model of the crane planner is explained as well as the validation results.

## 2. CONSTRUCTION PLAN

In the building trade, there is a growing realisation that the work preparation phase is crucial to the building process. To achieve maximum output in the construction process, an integrated plan for that process has to be designed: the Construction Plan (see figure 1). The process designer creates the best possible construction plan with the help of Decision Support Systems. A specific theoretical framework for that plan is a platform for the approach we have chosen to developing a decision support tool for the use of cranes in the construction process.

A database where all information can be stored is a major part of the process of designing the Construction Plan. Information can be external (architect or supplier) or internal (the tentative results of the Construction Plan).

This theoretical framework consists of a number of related plans and scenarios (see figure 2). Leijten et al. distinguished a collection of plans and scenarios in the Construction Plan. A plan contains data on a specific production aspect like setting up, safety or equipment needs. All data on the production of a single part of the project or a building element are included in a scenario.

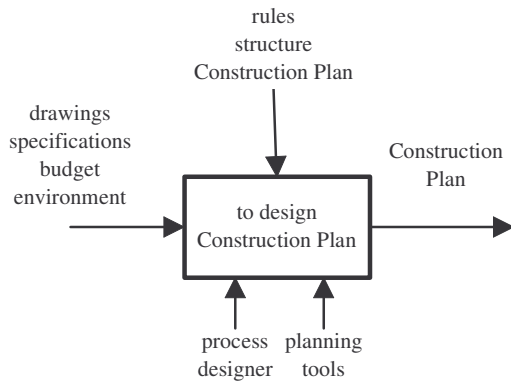


Figure 1. Input and output designing process of Construction Plan.

The plans and scenarios are represented in a diagram: the plans are shown horizontally and the scenarios vertically. The information for the plans and scenarios comes from a single database.

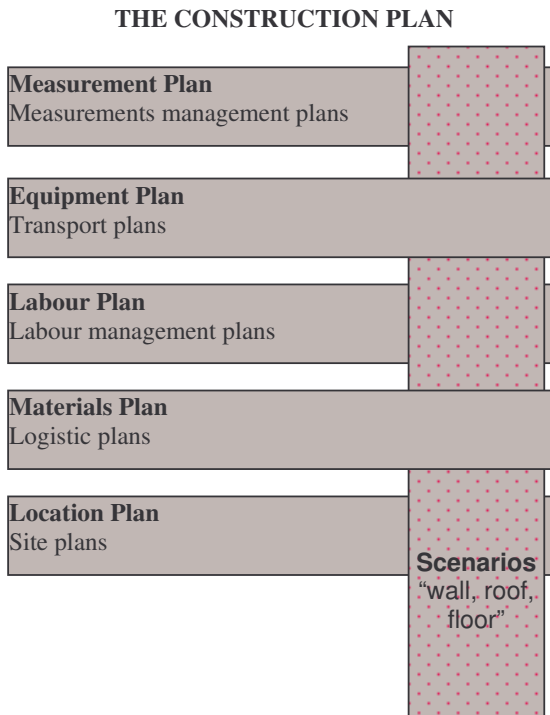


Figure 2. Schematic Layout for the “Construction Plan”. The “sub-plans” are listed horizontally. The scenarios for producing building parts, which are interrelated with the “sub-plans”, are listed vertically. [6]

### 3. TRANSPORT AND CRANE PLANS

The Transport Plan is a specific part of the Construction Plan. This can be described as follows:

“A transport plan is a set of documents that describe how, during the production phase of a building, the material and equipment transport is organised to, on and from the construction site.” [2]

The Transport Plan consists of the following documents:

1. Transport specifications of materials and equipment.
2. Transport equipment specifications.
3. Transport equipment planning.
4. Layout of construction site.

The Crane Plan is a sub-plan of the Transport Plan. Examples of other sub-plans would be a concrete transport plan or a plan to transport workers.

In the literature, we found different kinds of tools to design a crane plan. First, there are the crane manufacturers, such as Liebherr or Potain, who have made software programs for choosing crane types. The properties of the crane chosen and the situation at the construction site can be reviewed on a laptop screen.

The Technical University of Munich designed a tower crane-planning tool. Inputs are the load, radius and hoist height. The output of the planner is the crane type [10].

On the Internet site [www.liftplanner.com](http://www.liftplanner.com), there is a planning application by A.P.M.S. Qld Pty Ltd with the same properties as the Munich application.

Gray and Little [4] designed an expert system for the selection of an appropriate mobile or tower crane for a construction site. The system contains tips for the crane planner for making decisions. The output is the crane profile. A cost calculation is not provided.

Van Dijk [1] developed an expert system that comes up with a crane profile. This system can be integrated on the Internet and is used to generate a flow chart.

Williams and Bennett [9] designed an Automated Lift Planning System (ALPS). It is a graphical crane and rigging simulation tool for simulating heavy lifts and preparing lift plans. ALPS allows users to graphically simulate the entire lift sequence, animate the process, and play back the lift either online or on video in order to communicate the lift plan to others. The software is available.

Ito and Kano [5] designed a 3-D graphical simulation for crane planning using an object-oriented building product model that supports simulation, visualisation and documentation of crane planning with user-friendly interfaces. The most important point in developing this system is that it proved the concept of the new type of 3-D graphical simulation with evaluations of cost, scheduling and other planning factors.

In the ISARC15 paper, Van Gassel [3] distinguished three levels of crane planners: long-term, one-day

and online planning tools. He reaches the conclusion that these planners must be integrated. At the University of Texas, some studies on lift planning have been carried out. See Internet site [www.ce.utexas.edu/prof/haas](http://www.ce.utexas.edu/prof/haas). The subject of these studies is heavy lifts.

#### 4. CRANE PLAN WITHIN THE CONTEXT OF THE TRANSPORT PLAN

As explained in the introductory sections 1 and 2, the approach for developing the Construction Plan is based on the idea of a set of well-described and “interrelated” (interactive) plans and scenarios. In terms of the system theory, the Transport Plan is a system, the boundaries of which consist of the Construction Plan system. The Crane Plan can be interpreted as a system within the boundaries of the Transport Plan system. In figure 3, the relationship between systems and sub-systems is represented with the notation “Structured Analysis and Design Technique” [7].

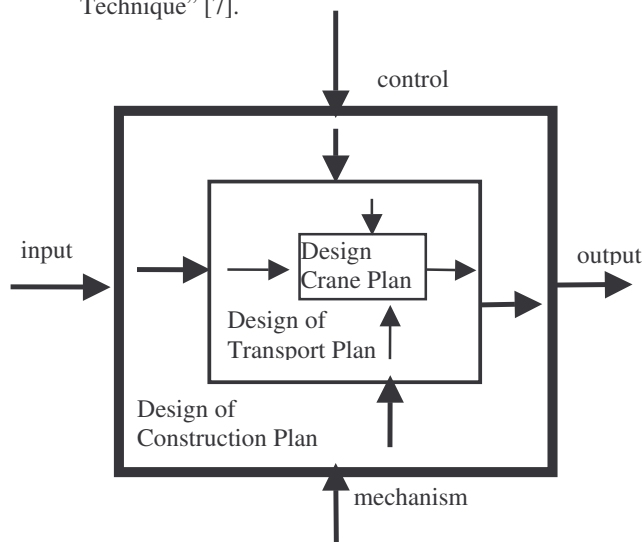


Figure 3. Schematic representation of the Crane Plan as a system within the Transport Plan, which is a system within the boundaries of the Construction Plan.

After analysing available developments for crane plans and considering experiences with the aforementioned crane planners in section 3, a “new” crane planner has been developed that fits within the context of the Transport Plan, as a part of the Construction Plan.

This Crane Plan is described as follow [8]:

“A crane plan tells about costs, cranes, where and when to transport particular building parts from where to where.”

More specifically, the Crane Plan is defined by its output, which is stated as:

- the position of the crane on the construction site,

- the specification of the crane,
- the planning of the hoist activities,
- the costs of the crane plan,
- building parts to transport by crane,
- pick up and deposit sites for building parts.

Some other outputs can be used as input for the database. See figure 4.

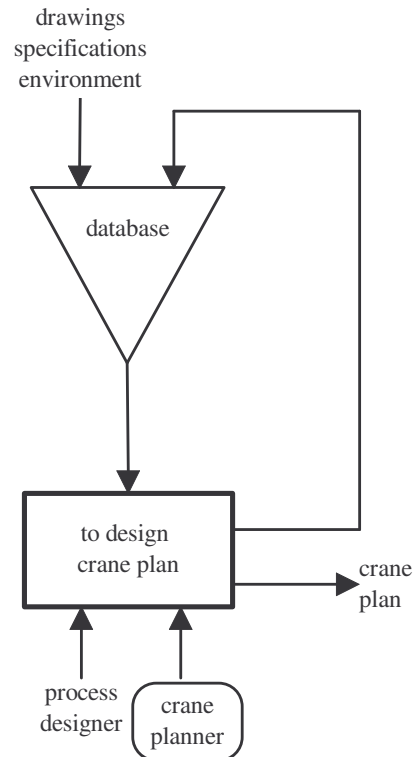


Figure 4. The design process of a crane plan.

The database consists of the following information items:

- Environment: condition of the soil, surrounding buildings, building site, etc.
- Building: building materials and parts, details, building methods, etc.
- Project: contracts, prices, laws, etc.
- Cranes: types, specifications, costs, hoist equipment, etc.
- Knowledge: rules, tips, etc.

Some of this information is incorporated in the plans and scenarios of the (tentative) construction plan.

#### 5. THE MODEL OF THE CRANE PLAN

The four elements of the model of the Crane Plan are:

1. Knowledge base.
2. Procedures base.
3. Data processing.

#### 4. User interfaces.

##### 5.1 Knowledge base

The model can store knowledge in the database of the construction plan. The knowledge has been gathered from the literature and from interviews with experts in the construction industry. With this knowledge, the crane planner can make decisions according to the rules in the system. The process designer can also make decisions based on knowledge in the system or his own knowledge.

Some examples of these rules are:

- For three-month use of a crane, a tower crane is indicated.
- The distance between two tower cranes is five metres.
- Minimal distance between crane and surroundings.
- Minimal distance between the jib of two tower cranes.

##### 5.2 Procedures base

The model contains the following main procedures:

1. To determine crane effort.
2. To determine crane type.
3. To determine crane position.
4. To specify crane.
5. To determine crane costs.
6. To set up crane plan.

Each main procedure consists of four to six sub-procedures.

These procedures use a database with information about: crane properties, subscriptions about crane use, safety laws, etc.

##### 5.3. Data processing

The crane planner is developed by making use of the Delphi 3.0 programming environment. The application runs on a standard Windows 95 computer. This paper does not give a description of this development. The whole program consists of 90 screens for the user interface.

##### 5.4 User interface

The main menu of the crane planner comprises the same six steps as described in section 5.2

The structure of the screens is:

- one part for the menu and a tree view (where the designer is in the design process),
- one part for the input of information and
- one part for showing the tentative results of the crane plan.

Examples of screens with tentative planning results are:

- A 3-D drawing of the building. The building parts which had to be transported by crane are highlighted
- Long-term planning of the building process.
- A diagram on which the weight is indicated on the vertical axis and the radius of the crane on the horizontal axis.
- A crane scheme for a particular crane. In this scheme the crane planner can match the crane demand with several crane types.
- A 3-D drawing of the building with the chosen crane.
- An overview of the costs of the crane plan: transportation of the crane, foundation, assembling, hiring and operation.

## 6. RESULTS

In co-operation with Schepers and Woudenberg, we built a prototype of the crane planner and tested it on a building project. A Crane Plan was designed for the transport of prefabricated concrete columns and walls and for floor elements, reinforcement and concrete. In total, 7,070 building parts for five floors. Two methods were used to validate research output. One method was to use an expert panel for judging the output of "our" Crane Plan for a hypothetical project. The second method was to put all the data and rules for a recently finished construction project into the databases of the Crane Plan and see if the suggestions made by our program for choosing the cranes were similar to those that had been made in the real world of the finished project.

*The strong points are:*

- Automatic calculation of the degree of capacity utilisation and drawing of crane diagrams by the computer. It would take too much time to do this by hand.
- It is now possible to design and evaluate two crane plans.
- In the Crane Plan, the process designer can make his own decisions and the system helps him with time-consuming work.
- Giving the process designer tips and rules is very useful. In this way, knowledge becomes available to more people.

*The weak points are:*

- Not all the information needed to work with the planner is available to the construction firm. The drawings for the building must be supplied in CAD files.
- When the designer wants to change something he has to go through the whole program.

- What will the economic benefits of this rather expensive DDS tool be?

## 7. DISCUSSION

The Crane Plan was developed within the rigid context of a theoretical framework for designing construction processes. This framework has been addressed in sections 2 and 4. The whole of the research effort demonstrated the idea that a set of interrelated design decision tools has to be available for designing construction processes. On the other hand, the stand-alone performance of the Crane Plan was interesting. The real-world experts were satisfied by the program's output.

From this perspective, one major step forward in modelling our framework for the Construction Plan has been accomplished. Other sub-plans must be developed, also taking into account the function and reliability of the sub-plan itself and the way such a tool is interrelated with the other decision support tools in the "Construction Plan".

The next steps in developing this tool for crane planning are:

- To complete the software programs: connecting the object-oriented drawing and planning software.
- To gather more knowledge.
- To integrate the crane planner with the other tools used for designing the construction plan.

## ACKNOWLEDGEMENTS

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