COMPUTING INTERDEPENDENCIES BETWEEN PLANNING AND CONSTRUCTION ACTIVITIES

Wolfgang Huhnt[1]

ABSTRACT

Project preparation phases in civil engineering are predominantly based on experiences. Project manuals and work plans are written out. They cover relevant project information. Information systems are already used in project preparation phases, but these systems are used for documentation purpose only. As a consequence, the results cannot be checked on a formalized basis. Only experts are able to find inconsistencies.

This paper is focused on scheduling tasks in civil engineering where schedules can cover several thousands of activities. It is always expensive to work out these schedules, and it is also expensive to check them. The approach presented in this paper is based on the consideration that information in schedules can be computed. A modeling technique is presented to compute compulsory interdependencies between planning and construction activities. These compulsory interdependencies need to be considered in any case. Therefore, a basis is generated that can be used to develop a schedule. This basis is transferred to an existing scheduling tool and additional information like durations and expedient interdependencies need to be added by a project manager to complete the schedule.

Experiences from planning processes showed the advantages of using computations for compulsory interdependencies between activities. Project managers can specify schedules more efficiently and the rate of inconsistencies is reduced.

KEY WORDS

computational management, process modeling, planning processes, construction processes, construction management.

INTRODUCTION

A lot of investigations have been done in the past to use computers for supporting scheduling in civil engineering. Network planning techniques like the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM) have been developed in the 1950th, and efficient algorithms are available to execute the computation for e.g. the determination of the critical paths. (Berrie Paulson 1992) Also a lot of algorithms have been developed in Operations Research, for instance to determine schedules where cost is minimized. (Runzheimer 1999) However, all these algorithms require a set of activities, interdependencies between these activities, and durations as input. This paper is focused on

[1] Professor, Berlin University of Technology, Institute for Civil Engineering. Sekr. TIB 1 – B 13, Gustav-Meyer-Allee 25, D-13355 Berlin, Germany, Phone +49 30 314 72228, FAX +49 30 314 72406, huhnt@tu-berlin.de

using the computer to compute some of this information. So, the use of the computer is expanded to an area where at present time no computations are used. The reason for this research is that traditional ways of specifying all scheduling information are expensive and prone to errors. A lot of schedules in civil engineering practice cover inconsistencies. However, these inconsistencies are always detected during the project execution phases, and it is always expensive to redefine activities and schedules.

As a nature of computations, input information is always necessary. The methods presented in this paper require the specification

- of planning results like documents, reports, or technical drawings,
- of construction results like walls, ceilings, or floors,
- of planning activities like writing a structural report and
- of construction activities like laying bricks.

Based on this user input, compulsory interdependencies between activities are computed. These interdependencies need to be considered independently of any aim that has to be achieved in scheduling. Therefore, a coordinated basis for scheduling is available. Of course, this basis depends on user input, but it is much more efficient to specify this user input rather specifying all compulsory interdependencies in schedules that cover several thousands of activities.

COMPULSORY INTERDEPENDENCIES

Schedules need a complete list of activities as input. Based on this input, information of different natures needs to be added:

- compulsory interdependencies,
- compulsory durations,
- expedient interdependencies, and
- expedient durations.

Compulsory interdependencies result from the logic of the process. For instance, plastering a wall requires that brickwork has to be completed. Compulsory interdependencies need to be considered independently of all other information. Errors in compulsory interdependencies cannot be solved by for instance more resources. They are errors, and they require always a rescheduling. Compulsory durations can be regarded as weights that have to be considered. For instance, waiting periods need to be considered after plastering a wall before it can be painted. Compulsory durations depend on building materials and manufacturing methods.

Expedient interdependencies and expedient durations depend on specific aims. For instance, the aim to execute a project with restricted resources results in interdependencies and durations that can be totally different if a schedule has to be developed where a specific end date is fixed and the number of resources is not restricted.

In this paper, only compulsory interdependencies are regarded and it is explained how these interdependencies can be computed in civil engineering projects.

SPECIFYING PLANNING RESULTS

Results of planning phases in civil engineering are information which is usually documented in reports, technical drawings, meetings minutes, etc. In project preparation phases, the number and the kind of documents are determined. This is based on the experiences of the people involved. For instance, a structural engineer knows the number of reinforcement drawings that are necessary to be worked out for a specific ceiling with specific dimensions, loads, and supports. Usually in preparation phases all documents are named and calculation methods used in engineering companies require such a list of document names as input.

Figure 1 shows a simple example of a construction. The list of documents that need to be worked out in the planning process – in this example reports and technical drawings – is shown in table 1. However, reports and drawings are reworked in civil engineering projects. This can be expressed by a status variable. (Huhnt Lawrence 2004) A specific planning task has specific documents in specific states as results. Table 2 shows the status variables that are assigned to the specific documents in the example.

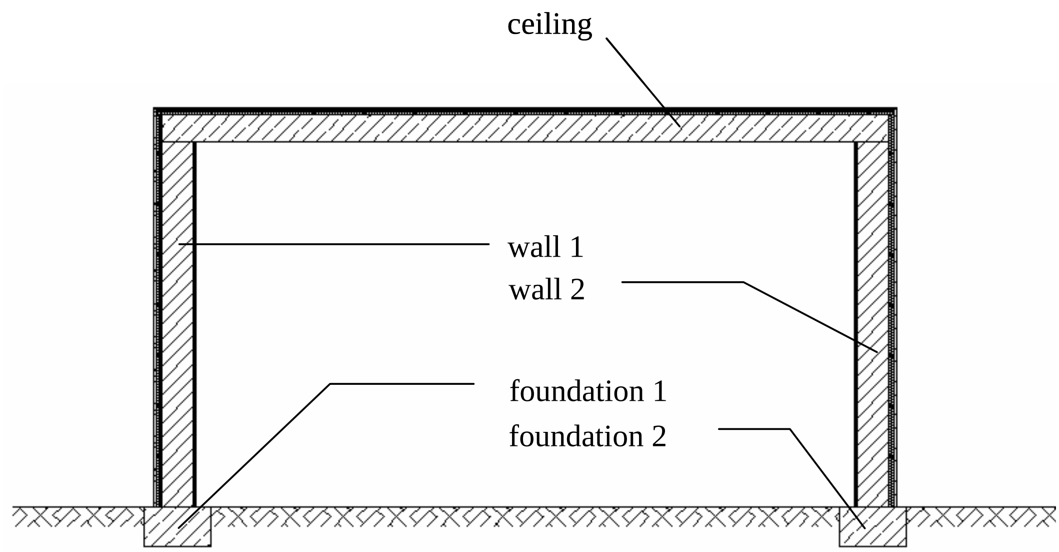

Figure 1: Corss section of a construction

The concept presented in this paper requires the specification of the content of documents. Documents describe components, and it is necessary that a “table of contents” is assigned to each document. Table 3 shows such a “table of contents” for the example shown in figure 1 and table 1.

Table 1: Reports and drawings

Documents
architectural drawing
architectural design report
structural design report
foundation concrete layout drawing
foundation reinforcement drawing
ceiling concrete layout drawing
ceiling reinforcement drawing

Table 2: Status variables for reports and drawings

Documents	Status Variables
architectural drawing structural design report	preliminary engineered checked
architectural design report	preliminary final checked
foundation concrete layout drawing foundation reinforcement drawing ceiling concrete layout drawing ceiling reinforcement drawing	engineered checked

SPECIFYING CONSTRUCTION RESULTS

Results of construction activities are components in specific states. As shown in figure 1, the example covers five components, foundation 1, foundation 2, wall 1, wall 2 and ceiling. Modeling status variables of components requires enhanced concepts than a sequence which can be used to model status variables for documents. Components have different surfaces, and it can happen that different states need to be modeled for different surfaces. (Enge 2005) For instance, an interior wall can be painted on one side whereas tiles are necessary on the other side. In our example, only concrete work and brickwork are regarded. Therefore, a sequence of status variables is sufficient for each component. These status variables are shown in table 4.

Table 3: Table of contents of reports and drawings

Documents	Components
architectural drawing architectural design report structural design report	foundation 1 foundation 2 wall 1 wall 2 ceiling
foundation concrete layout drawing foundation reinforcement drawing	foundation 1 foundation 2
ceiling concrete layout drawing ceiling reinforcement drawing	ceiling

Table 4: Status variables for components

Components	Status Variables
foundation 1 foundation 2	formwork placed reinforcement placed concrete placed formwork stripped
wall 1 wall 2	brickwork completed
ceiling	formwork placed reinforcement placed concrete placed formwork stripped support removed

SPECIFYING PLANNING ACTIVITIES

Planning activities are specified by their prerequisites and their results. Prerequisites and results are documents in specific states. Examples are shown in figure 2 for the construction in figure 1.

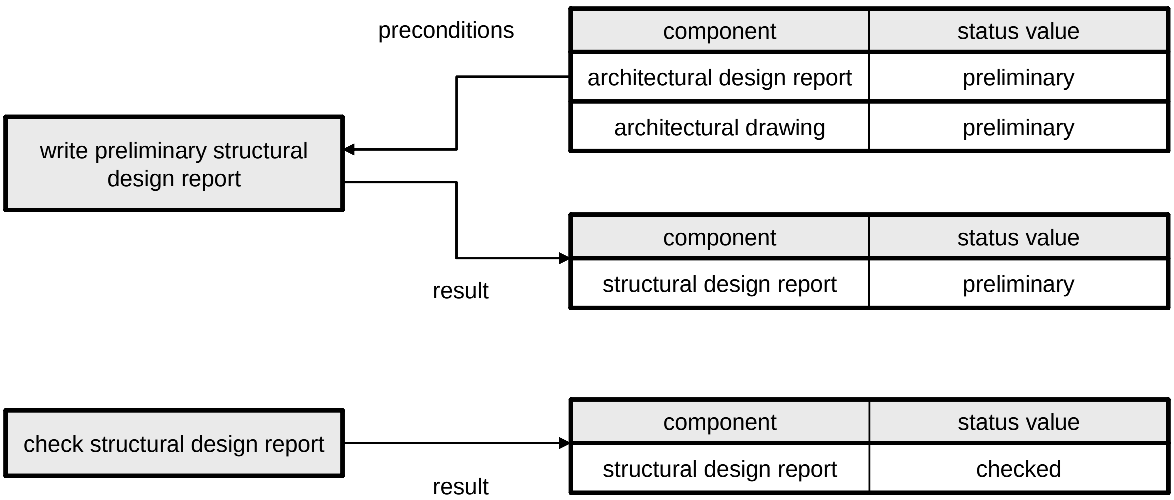

Figure 2: Examples of planning activities

Specifying planning activities by specifying their prerequisites and their results is a suitable modeling technique. People think in activities. Experts know exactly what information they need for the execution of a specific planning activity. This knowledge is available, and it is much easier to describe an activity by its prerequisites and results rather thinking about the interdependencies to other activities. (Huhnt Lawrence 2004)

SPECIFYING CONSTRUCTION ACTIVITIES

The concept of specifying activities by the specification of prerequisites and results is also used for construction activities. Figure 3 shows examples that fit to the construction shown in figure 1.

Specifying construction activities by specifying their prerequisites and their results is a suitable modeling technique. Like in planning processes, people think in activities. Even construction workers know exactly the prerequisites that are necessary for the execution of a specific construction activity and the results that are expected. This knowledge is available. All construction activities need to be specified in an equivalent manner than shown in figure 3.

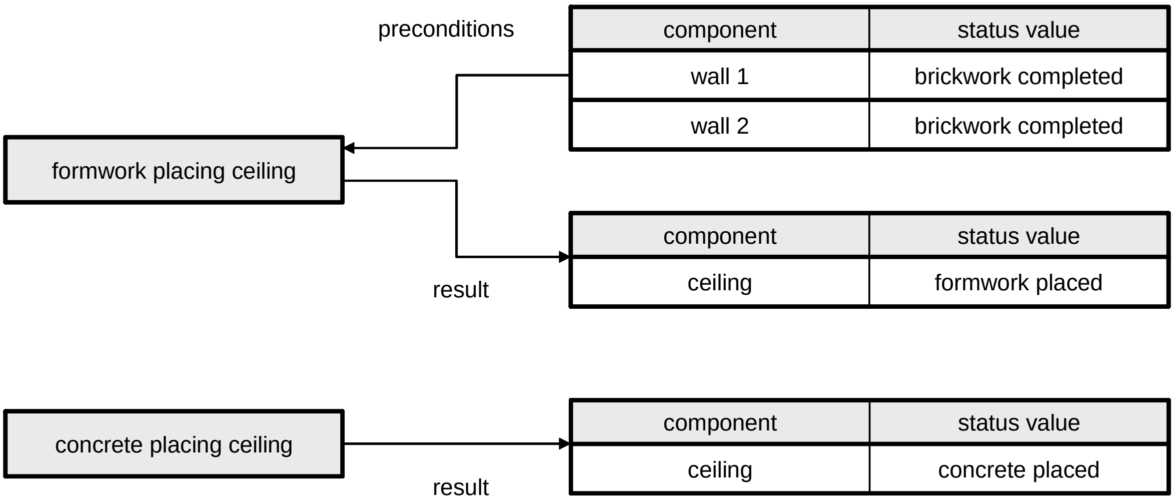

Figure 3: Examples of construction activities

COMPUTING INTERDEPENDENCIES

The rule "prerequisites must be completed" is evaluated for calculating interdependencies between activities. The theoretical background for the computation is based on Relational Algebra, specifically the concatenation of relations. The concatenation is executed for three different types of interdependencies:

- interdependencies between planning activities,
- interdependencies between construction activities, and
- interdependencies between planning and construction activities

In a loop over all planning activities, each planning activity is considered. If a planning activity requires a document in a specific state as its prerequisite, the activity is determined that has exactly that document in that state as its result. Interdependency between these two activities exists where the producer of the required result has to be executed before the user of that result. In addition, the results of each planning activity are checked. Each activity that modifies the same document to a status value less than the status value of the actual activity has to be executed before the actual activity. These calculations are theoretically based on relational algebra. The operation used in the product. (Pahl Damrath 2001)

Interdependencies between construction activities are computed in an equivalent way. (Huhnt 2005) All prerequisites of each construction activity are checked and interdependency between the producer of a prerequisite and the actual activity is determined. All results are checked and interdependency between the actual activity and all activities that modify the equivalent component to a state less than the actual activity exists.

Interdependencies between planning and construction activities are computed in such a way that each construction activity is checked. A construction activity has at least one component in a specific state as its result. All planning activities that are modifying documents that cover this component need to be executed before the construction activity can take place.

The algorithms for the calculation of the interdependencies are implemented in an efficient way so that they require an effort of computation less than the square of activities. The resulting structure consisting of activities and interdependencies is sorted topologically based on a breadth-first-search. The result is a sequence of activities where the sequence is as short as possible and each activity is executed at its earliest possibility.

Figure 4 shows such a sequence of planning and construction activities that has been transferred to an existing scheduling tool. A start date has been chosen, and the duration of each activities is preset by 1 day.

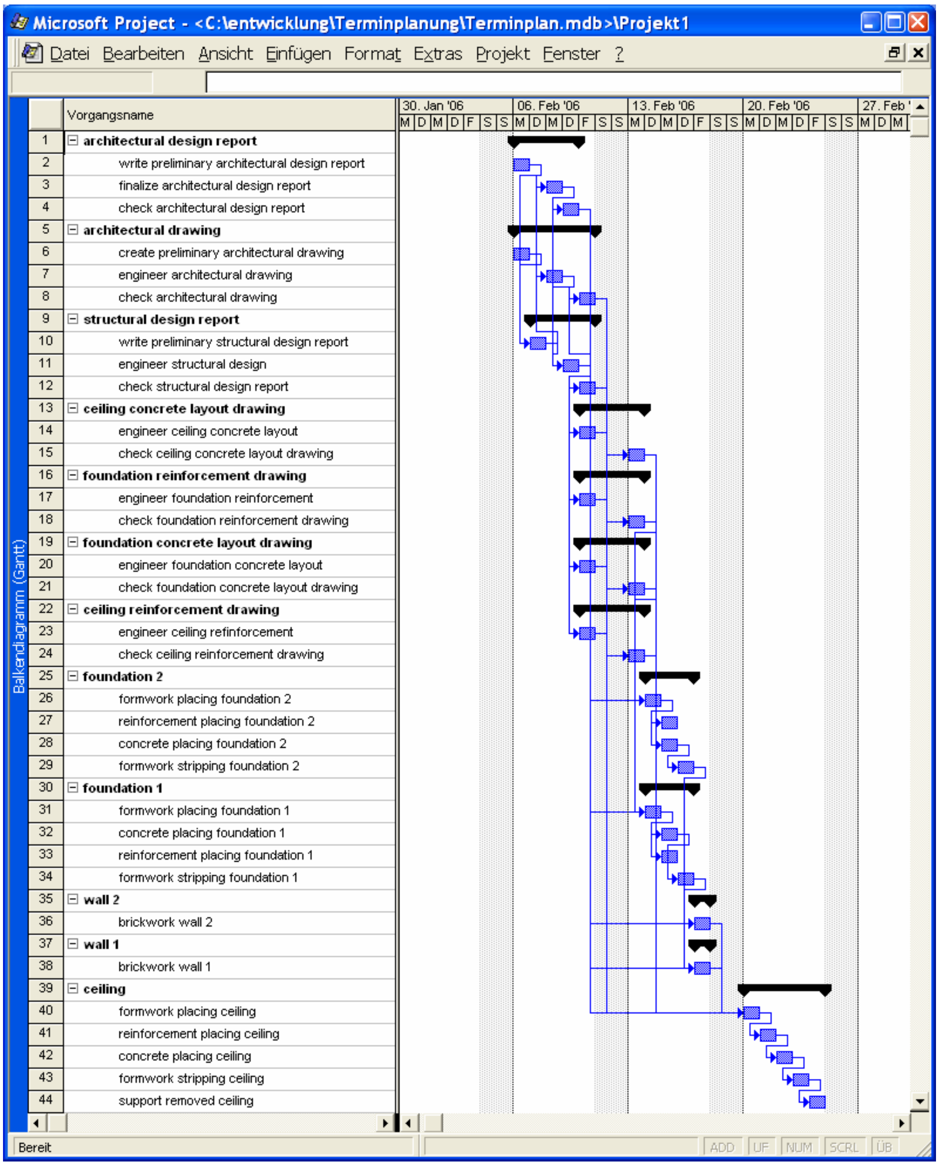

Figure 4: Computed interdependencies

PRACTICAL EXPERIENCES

The presented technique has been evaluated for planning processes. Realistic planning processes covering several thousands of engineering working hours have been modeled. The users told that they could develop the schedule much more efficiently. They saved time. And in addition to scheduling, the used the computed results and transferred them to an engineering management tool so that a coordinated basis for both, scheduling and controlling has been available.

CONCLUSIONS

At present time, the research is still in progress. A complete evaluation of the technique presented has not been finished jet. Some evaluations have already taken place, and the technique presented has been used for models with several hundreds activities. The computations are executed on usual PCs and the effort of computation is not critical. However, using the technique presented requires a different mode of developing schedules. The user has to distinguish compulsory information from expedient information. In a first step, the user has to focus on compulsory information only. And in a second step, he has to add expedient information. These different steps are not clearly distinguishable in existing tools for scheduling so that the technique presented requires modifications in scheduling. Computed compulsory information should net be editable after their computation, and modifications in the input where modified compulsory information is determined should be used in such a way that already specified expedient information can still be used. A lot of investigations are necessary to results in a practical tool. However, the technique presented promises to improve scheduling in civil engineering.

REFERENCES

Barrie, D. S., Paulson, B. C. (1992) *Professional Construction Management*. McGraw-Hill, New York, 577 pp.

Runzheimer, B. (1999) *Operations Research*. Band 1. Gabler, Göttingen, 7. Auflage

Enge, F. (2005) “Zustandsmodellierung als Grundlage für Ausführungsterminpläne” *Forum Bauinformatik 2005*, Brandenburg University of Technology at Cottbus, 123-130

Huhnt W., Lawrence J. (2004) “Methodik zur Modellierung konsistenter Soll-Vorgaben für komplexe Planungsprozesse in Bauwesen” *Bauingenieur*, VDI, Düsseldorf, 79 50-56

Pahl, P. J., Damrath, R. (2001) *Mathematical Foundations of Computational Engineering*. Springer, Berlin, 1008 pp.

Huhnt W. (2005) “Generating Sequences of Construction Tasks”, Proceedings of the 22nd CIB-W78 Conference *Information Technology in Construction*, Dresden, 2005, 17-22