Theme:

Title: **Determination of Effects of Modifications during Planning Processes**

Author(s): Timo Heinrich and Wolfgang Huhnt
Institution(s): Bauhaus-Universität Weimar, Informatik im Bauwesen
E-mail(s): timo.heinrich@informatik.uni-weimar.de
wolfgang.huhnt@informatik.uni-weimar.de

Abstract: *Usually, the co-ordination of design and planning tasks of a project in the construction industries is done in a paper based way. Subsequent modifications have to be handled manually. The effects of modifications cannot be determined automatically. The approach to specify a complete process model before project start does not consider the requirements of the construction industries. The effort of specification at the beginning and during the process (modifications) does not justify the use of standard process model techniques.*

A new approach is presented in this paper. A complete process model is deducted on the base of a core. The core consists of process elements and relations between them. Modifications need to be specified in the core only. The effort of specification is therefore reduced. The deduction of the complete process is based on the graph theory. Algorithms of the graph theory are also used to determine the effects of modifications during the project work.

Keywords: *Computational Management, Planning Processes, Process Model, Graph Theory*

Introduction

Design and planning processes in civil and building engineering are executed by several specialists in distributed environments. Usually, the execution of design and planning tasks are planned during a preliminary project phase in a paper-based way: meetings are organized in which tasks and responsibilities are determined and the data flow is fixed; the results of these meetings are documented in meeting notes and protocols. On the base of meeting notes and protocols, software systems are customized to support co-operative work like document management systems, workflow systems or systems to store and distribute plans. Further agreements are documented in project manuals.

The disadvantage of this proceeding is that a common base is missing: Subsequent modifications which are usual during design and planning processes need to be tracked in several systems; the effects of this modifications can not been determined automatically.

This paper is focused on an approach to use process models in the preliminary project phase. A core of the process model is set up which describes the predefinitions for the design and planning phase. It is completed by the execution of algorithms to describe the whole design and planning processes. Modifications are specified on the base of the core. Their effects can be determined automatically using the same theoretical background for both: the determination of a complete model as well as the determinations of the effects of modifications.

Process Models for Planning Processes

As well approved in other industries, a process model for planning and managing activities within a project consists of sets of process elements and enforces the specification of relations between them. Design and planning activities require persons involved in the project. The execution of the whole project has to be divided into several tasks, which has to be done by project participants. So two sets (as of persons and tasks) and one relation between these two sets need to be considered. The information created, used, modified during the execution of tasks have to be modelled to co-ordinate the exchange of data between the project participants. It is not allowed to delete information because the design and planning processes including the information need to be documented. Therefore, three relations between tasks and information describe whether a specific information is created, modified or simply used (read) during the execution of a specific task. The tasks have to be done by persons under utilisation of several AEC-software tools. A relation between information and tools denotes the tool used to work on a specific kind of information, whereas a relation between tools and tasks accumulates the tools necessary for the execution of a specific task.

Specific Requirements in the Construction Industries

In general, it is not useful to specify a process model on the whole before the project starts. The effort of specification is enormous. In addition, a complete process model is over-determined and a large number of modifications take place in design and planning processes. The benefit in using a process model does not justify the effort of specification using existing tools and methods.

Specifying a Core

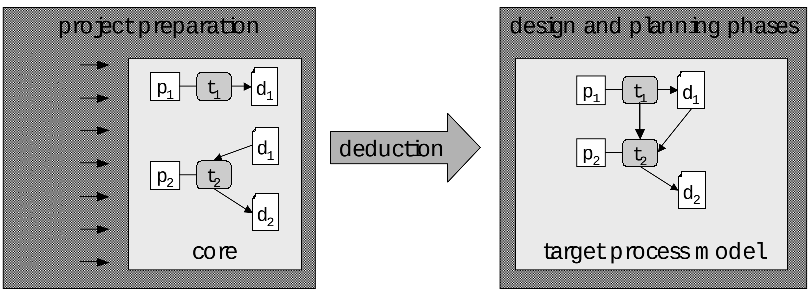
Based on this considerations, only a subset of a process model is specified at first. The subset (so called core) consists of the set of tasks which have to be executed, the set of persons which execute tasks, the set of information, the relation between tasks and persons and the relations between tasks and information. The specification has to be done by a project co-ordinator or a co-ordination team. Then this subset is used to determine a complete and valid process model.

Determination of a Complete Model

The determination of a complete model is based on the graph theory. It can be deducted on the base of the adjacency matrices. The set of tasks and the set of information are unified to a set of nodes. A set of edges is constructed on the base of relations between tasks t and information (data) d as follows: The relation *create* (R_{create}) is treated as directed edges between tasks and information, the relations *change* (R_{change}) and *read* (R_{read}) are treated as directed edges between information and tasks. The sequence of tasks ($R_{sequence}$) can be determined on the base of these relations as shown in Eq. (1).

$$R_{sequence} = R_{create} \circ \left(R_{change} \cup R_{read} \right) \qquad (1)$$

The sequence of tasks is ordered by a topological sort algorithm. In general, this result is not unique. The solution which is selected from the solution set sorts each task in such a way that it occurs at the earliest level where it is possible to be executed.



Determination of a complete process model by specifying a core.

The project manager or the co-ordination team has the possibility to select another solution of the solution set. The selection of another solution requires the specification of additional relations

$$R_{additional} \qquad (2),$$

e.g. task C has to be executed before task A. The property of each solution is that the graph does not contain a cycle. This can be checked by efficient algorithms which have been developed in the graph theory. The resulting sequence of tasks is determined on the base of sequence of tasks ($R_{sequence}$) and the additional relations ($R_{additional}$):

$$R_{resulting} = R_{sequence} \cup R_{additional} \quad (3)$$

Simple Modifications

If a simple modification takes place, the effects can also be determined by path algorithms. Simple modifications are modifications of information. If information is modified the dependent information are all information which can be reached by a path in the graph. The set of tasks which might be executed again is build upon all tasks which can be reached by a path beginning at the modified information and the task that creates the modified information.

Types of Modifications

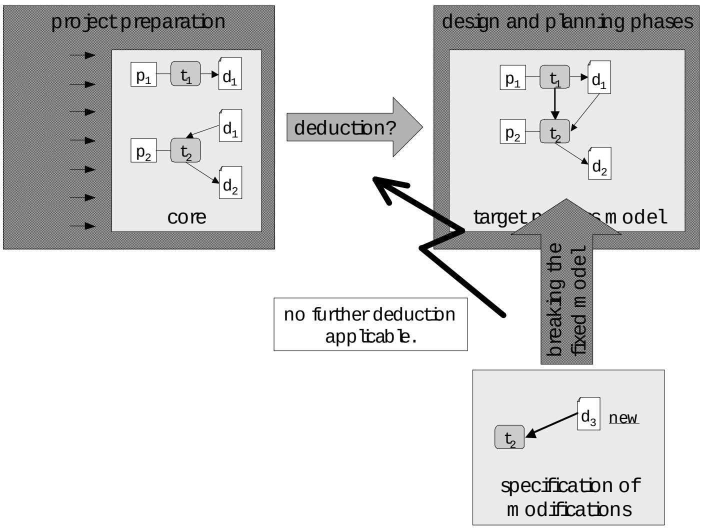
During the execution of construction projects lots of unexpected events may occur, for instance unexpected problems with the soil or modifications regarding the usage of parts of a building, etc.

Some kind of modification concerns information. These modifications do not effect the structure of the project itself, but often enforce the reapplication of some tasks. Generally, dependent information have to be checked whether they are still valid or not. As a part of the chosen approach these effects are determined and visualised to inform the project participants about the possible changes.

Further kinds of modifications affect the structure of the process. Modifications in the structure base on the introduction of new project participants and project partners, additional tasks which have to be executed, also some of them driven by further information. New project information introduced in the project also requires additional relations between tasks and persons and tasks and information and affect the project structure.

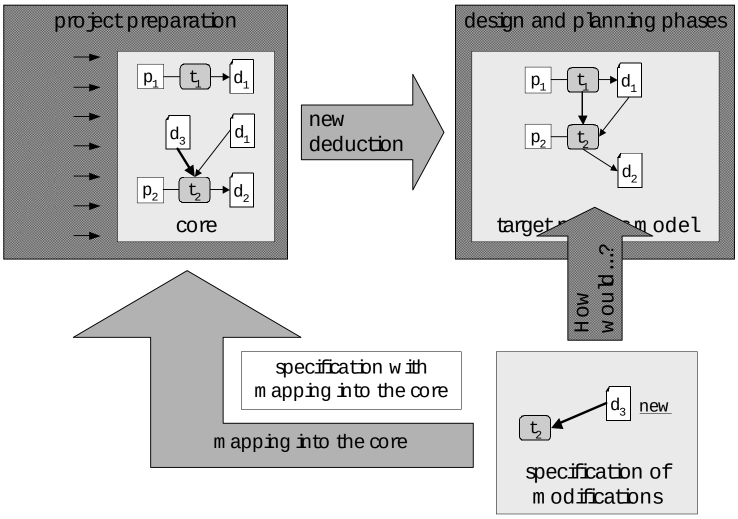
Specifying Modifications

Using standard process model techniques would require the consideration of modifications within the (fixed) target process model for the whole project. As a consequence, a new target process model containing the modifications is derived from the current one. So at least a version management at the level of the process model is required. The benefit from using a core to derive a whole process model is not applicable any longer.



Conventional change management.

So the goal of the new approach – as of specifying the project specific predefinitions at the subset, subsequently called core – is to provide the specification of modifications at this subset level, too. If modifications can be included into the core successfully like the originally predefinitions of the project, it is possible to determine a new target process model in the same way as aforementioned. The resulting benefit is to generate a new consistent process model using this way – not to modify an existing one.



Mapping modifications into the core.

Therefore, the modifications are specified on the base of the core. A new core is set up which contains the old predefinitions including the modifications.

Considering executed Tasks

The modifications to be handled occur during the execution of the project. Some tasks are executed whether nobody worked on other tasks:

$$R_{executed} \subset R_{resulting} \qquad (4)$$

According to the general purpose to deduce a whole process model from the core, this set of tasks must be mapped and added to the core. This mapping is possible by adding specific relations to the core. These are relations in the set of tasks in order to fix the state of tasks already done. Of course, these additional predefinitions catch some degrees of freedom the old target model left to the project co-ordinator before. But this means no further restrictions to the sequence of tasks remaining to be done.

Determination of Effects

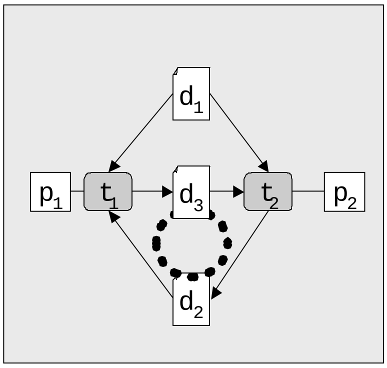
The determination of the effects of the modifications is executed on the base of a new process model. This new process model is determined on the base of a new core *C*:

$$C_{new} = C_{modified} \cup R_{executed} \cup R_{additional} \qquad (5)$$

The algorithm to determine the complete process model is the same as described above. Three different cases can be considered: The solution set is empty, the solution set consists of a single solution, the solution set consists of several elements.

The Solution Set is Empty

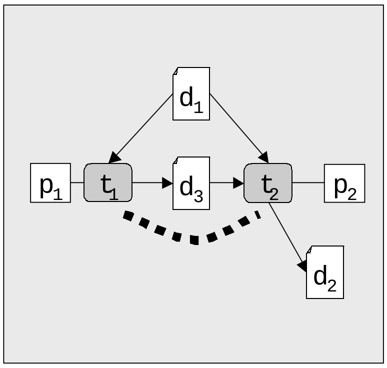
The solution set is empty if the model is overdetermined. In this case, too much restrictions have been specified. The effects of the modifications can not been determined because the resulting new process model contains a cycle. The following figure shows two tasks t_1 and t_2, each requiring data from the other one. So the circle in the graph is anticipating a sequence of execution for that tasks.



An Inconsistent Sequence.

The Solution Set Contains a Single Element

If the solution set contains a single element, the solution has to be accepted by the project team. The figure shows the only possible sequence of tasks t_1 and t_2 subject to the dependencies of data d_3.



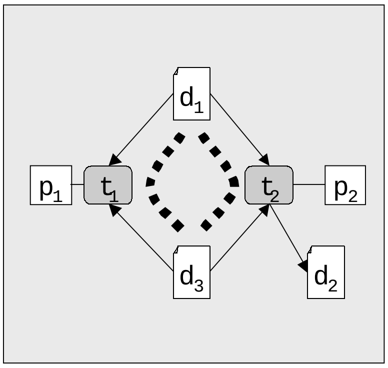
Only one sequence is possible.

The effects E of the modifications can be determined by comparing the new process model P_{new} with the older one P_{old}:

$$E = P_{new} - P_{old} \tag{6}$$

The Solution Set Contains several Elements

If the solution set contains more than one element, the accepted solution can be chosen by the project manager or project team as described above.



More than a single sequence is possible.

The selected solution is taken to determine the effects of the modifications using equation 6.

Conclusions

The presented method shows the use of process models for the co-ordination of construction projects. This was achieved by a specific approach which considers particularities of construction processes a priori: Modifications and alterations during typical construction projects in the building industries.

The approach is suitable to determine the effects of modifications during design and planning processes. This is achieved by formulating the problem on the base of the graph theory. Existing algorithms can be used to determine the effects of modifications in an efficient way.

The presented results are the first steps to establish such kind of use of process models for co-ordination tasks. In general, it has to be examined which kind of modifications can be appropriate mapped into the core more closely. Further research work is necessary to enlarge the focus so that a wider range of co-ordination aspects can be supported.

Acknowledgements

The results which are presented in this paper have been worked out as a part of the *Collaborative Research Center 524* (CRC 524) *Materials and Structures in Revitalisation of Buildings* which is sponsored by the *German Research Foundation* (DFG). The authors thank Daniel Beer from Bauhaus University Weimar for his contribution to the research work.

References

Pahl, P.J., Damrath, R., (2000), “Mathematical Foundations of Computational Engineering”, Springer Verlag, Berlin, 2001

Turau, V., “Algorithmische Graphentheorie”, Addison-Wesley, Bonn, 1996

Huhnt, W., „Process Models as a Base for the Co-ordination of Construction Projects”, Proceedings of The Ninth International Conference on Computing in Civil and Building Engineering ICCCBE, Taipeh, 2002