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Modification Management for Planning and Construction Processes

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Abstract. *This paper presents an approach to handle different types of subsequent modifications in civil engineering planning and construction processes. It is focused on a formalized approach with the objective that effects of subsequent modifications are detected automatically. The approach presented in this paper makes use of an existing modeling technique to generate consistent target values for planning and construction processes from a minimal user input. It uses existing concepts for handling versions and dependencies between objects. The integration of these different concepts makes it possible to track effects of relevant types of subsequent modifications in planning and construction processes on a formalized basis, effects of subsequent modifications are detected by algorithm, different versions can be compared by algorithms; and different versions are stored so that subsequent modifications are documented. The innovation of the approach presented is the completeness. Effects of all relevant types of subsequent modifications in planning and construction processes are tracked on a formalized basis.*

1 Introduction

The approach presented in this paper makes use of an existing modeling technique to develop target values for planning processes in Civil Engineering, Huhnt and Lawrence (2004) [1] and for construction processes [2]. Planning and construction processes in civil engineering are characterized by the specialty that they need to be designed individually for each project. Individual buildings require individual processes in planning, construction and facility management. In practice, schedules from already finished projects are used as a basis for a new project. Adaptations are always necessary because of the individual circumstances of each project. However, schedules used in practice only document a process. They require a set of activities, the duration of each activity, and interdependencies between activities or prescribed dates for the beginning or the completion of activities as their input. It is not necessary to specify each interdependency, and completeness and correctness need to be checked manually. This is an extensive task, and this task has to be executed again and again if modifications are necessary, either in the preparation phases or during the execution of a project.

Subsequent modifications influence the process. A new version of target values for the remaining process needs to be set up; and it is necessary to compare versions. The approach presented covers these abilities. A new version of target values for the remaining process is developed by using the existing modeling technique. The comparison is executed on a formalized basis.

The paper starts with a short description of the used modeling technique for planning processes followed by construction processes and their interdependencies. The second section discusses different kinds of subsequent modifications in planning and construction processes. The third section describes the underlying graphs that are set up to manage these modifications. Section four describes how these graphs are set up during the specification of a process model. The use of the availability of these underlying graphs is described in section five. An Example is given to illustrate that subsequent modifications can be managed. The paper concludes with a summary and an outlook.

2 Modeling Technique

At Technische Universität Berlin, research activities have been carried out where a complete, correct and consistent process is regarded as a result of a computation. User input is necessary, but user input is restricted to selected information, whereas computations are used to derive a complete, correct and consistent process description from this user input.

The process modeling technique is based on the assumption that a process can be described by documents or components in specific states.

2.1 Planning Processes

The process modeling technique is based on the assumption that a planning process can be described by activities, documents in specific states, specialists, and tools. In and between these sets, several relations need to be known. Specifically

- the relation in the set of activities describing their sequence,
- the relation in the set of documents in states describing the history of the documents,
- the relation in the set of specialists describing the personnel loading, and

- the relation in the set of tools describing the tool loading

are of interest. These relations describe the relevant aspects of the process. The sets and the relations are shown in figure 1.

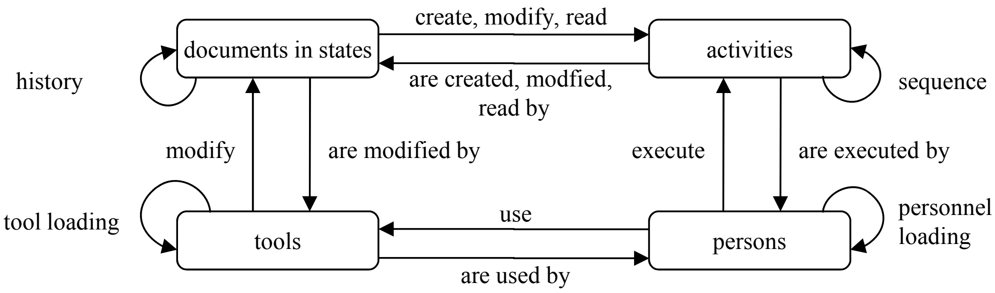

Figure 1: Sets and Relations of a Planning Process Model

The following relations are required as user input:

- document – milestone class (a milestone class defines states and their sequence)
- activity – document in state: input and output (create, read, modify)
- activities are executed by persons
- tools modify documents

The complete range of all other relations can be computed consistently to this user input by the execution of algorithms from relation algebra and graph theory, Huhnt and Lawrence (2004). It is appropriate to organize the status values in milestone classes valid for different types of documents. The modeling concept requires a specific mode of working to achieve a consistent process description. Sets and relations need to be specified in a specific sequence so that all other relations can be computed. This is shown in figure 2. To keep the descriptions in this paper simple, further considerations are focused on activities and documents in states only. The process elements, persons and tools can be added in the same manner.

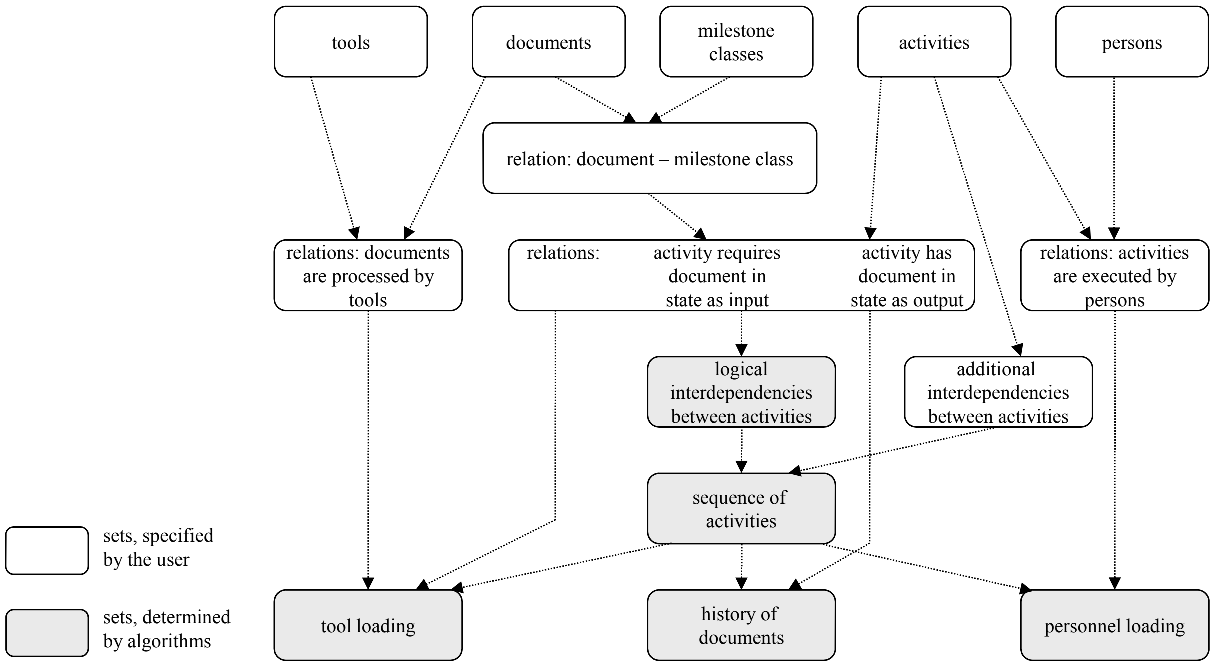

Figure 2: Specification and Computation of a Process Model for Engineering Planning Projects

A process model can either be used to describe target values for a project, or it can be used to document a project. Target values describe how a planning process has to be executed. They describe activities that need to be executed in the future and documents that need to be worked out in specific states during the execution of these planning activities. Project documentation requires an operational data logging. A log entry is required when an activity has been completed and when a specific document has reached a specific state.

2.2 Construction Processes

Results of construction processes are components. Components are manufactured, reconstructed or torn down during the execution of a construction project. During the execution of a project, a component passes through different states. A reinforced in-situ column, for example, passes through the following states:

1. formwork completed,
2. reinforcement placed,
3. concrete placed,
4. concrete set and required strength for stripping formwork reached,
5. formwork stripped.

In general, an acyclic graph is required to model the sequence of status values of components. This is the case, for example, for activities that are executed on different surfaces of a component. The complete process description of Construction Processes is shown in figure 3.

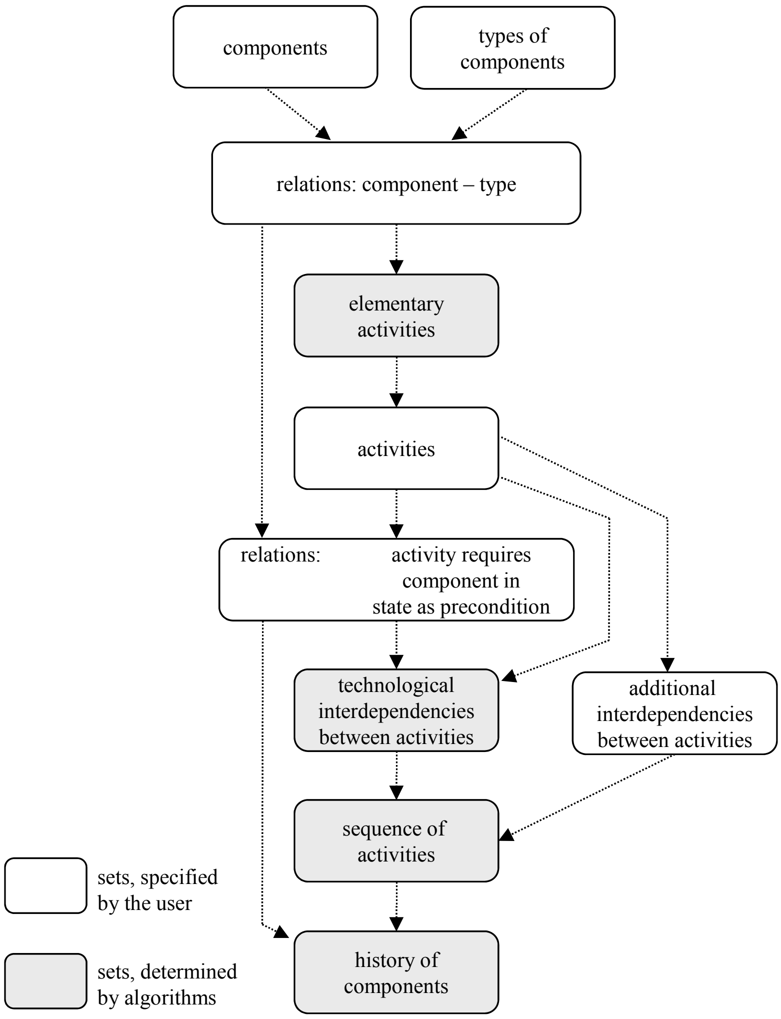

Figure 3: Specification and Computation of a Process Model for Engineering Construction Projects

Types of components are used to describe the manufacturing process of components. The modeling approach for construction processes requires a decomposition of a building into components. Each component needs to be assigned to a type. Elementary activities are introduced, and a pair of an elementary activity and a status value is modeled. The execution of an elementary activity results in the associated state. Prescribed durations for elementary activities are modeled as part of a component type, and an acyclic relation describes the manufacturing processes. Fig. 4 shows this component type.

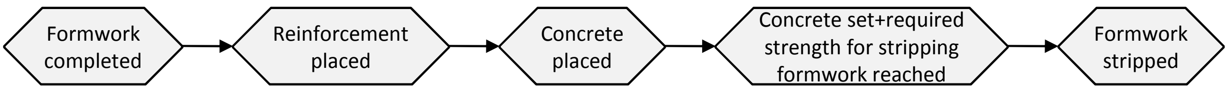

Figure 4: Type of Component

A list of elementary activities is computed, based on the relation between components and types.

2.3 Interdependencies between Planning and Construction Activities

Interdependencies between planning and construction activities can be considered in the modeling techniques presented so that a coordinated model can be derived covering both planning and construction activities in a consistent way. For this purpose, the units of data modeled as part of the planning process must know their content. It is necessary to specify a relationship between units of data and components. If this relationship is specified, interdependencies between planning activities and construction activities can be derived.

2.4 Planning and Construction Processes

Figure 5 describes the process model for planning and construction processes consisting of a process model for engineering planning projects and a process model for construction projects including the interdependencies between these models.

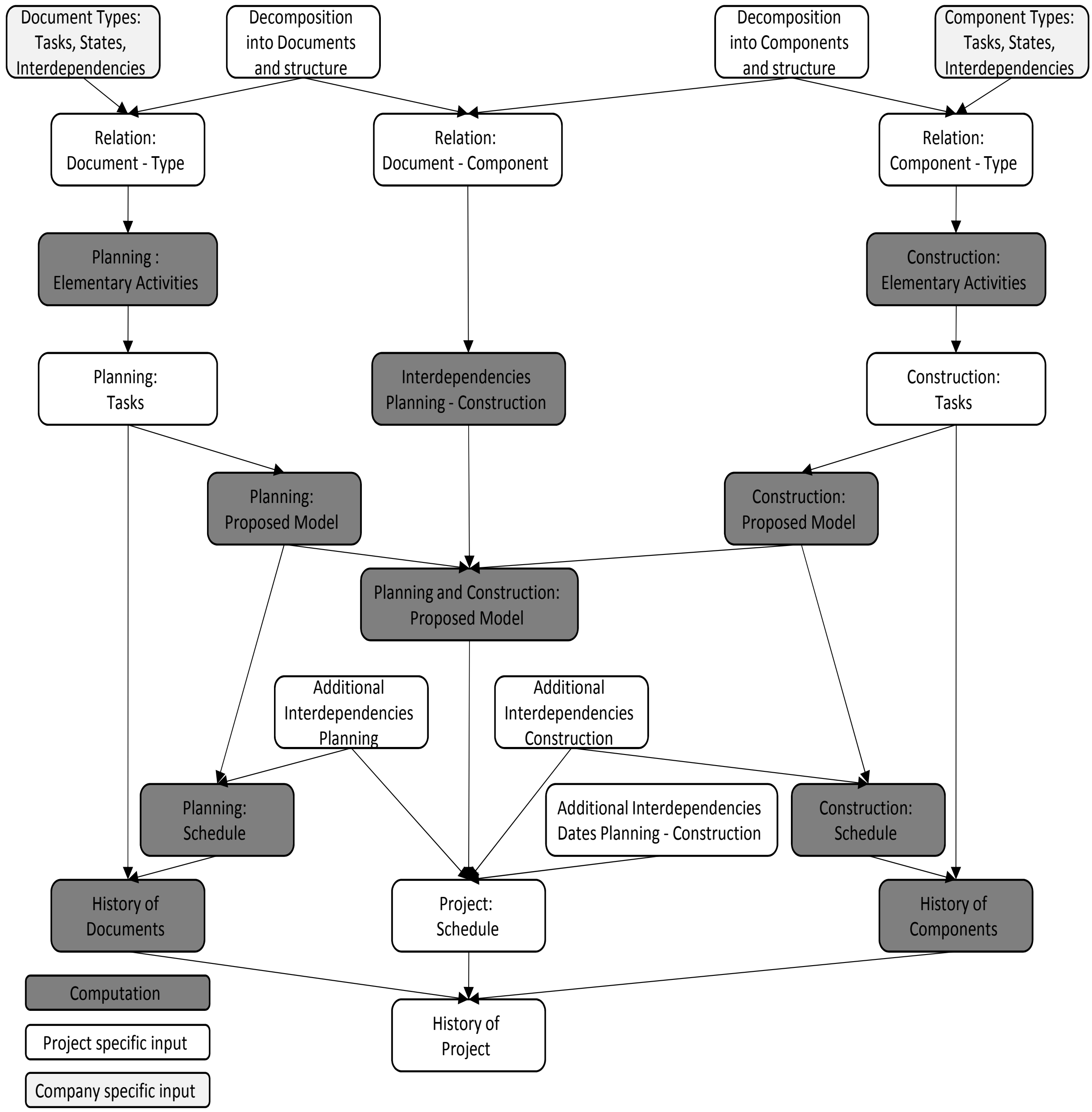

Figure 5: Specification and Computation of a complete Engineering Process Model

Figure 5 shows the principle parts of the resulting model, whereas figure 2 and 3 cover more details.

3 Subsequent Modifications

Three different kinds of subsequence modifications need to be considered:

- It is necessary to work out new documents or create new components.
- A subsequent modification can be necessary in a specific document or in a component
- It becomes obsolete to work out a specific document or a component is needless.

The following subsections describe these different kinds of subsequent modifications. Subsequent modifications need to be documented. The fourth subsection is focused on the need to document subsequent modifications.

3.1 Additional documents and components

During the planning process, additional documents are identified to be worked out. For instance, the client decides that he wants to install an air-conditioning system. As a consequence, additional documents need to be worked out in additional planning activities and additional components need to be manufactured and installed during the execution of construction activities.

Such subsequent modifications are equivalent to the specification of a process model. New process elements are instantiated. Relations to these process elements are specified, and a new sequence of planning and construction activities has to be generated. A formal comparison of the old and the modified new process model is necessary. The modifications need to be detected automatically.

3.2 Subsequence Modifications in documents and at components

An already existing document in a specific state is modified subsequently. Let us consider an architectural design drawing that has been worked out in the state assumed. The client decides that the location of a wall has to be modified. As a consequence, the already existing architectural drawing in the state assumed has to be modified. As a consequence, already executed planning activities need to be revised and already existing documents need to be modified. Also, construction activities need to be revised.

The objective is the detection of all potentially affected process elements by an algorithm. The consequence of such a subsequent modification is that the potentially affected activities need to be revised in a correct sequence. Thus, new target values for the process need to be generated where affected activities are considered.

3.3 Obsolete documents and needless components

During the planning process, it becomes obsolete to work out specific documents. Let us consider the decision that specific walls are now executed from masonry. Originally, they should be produced from reinforced concrete. As a consequence, formwork layout drawings and reinforcement drawings are not required and specific construction activities are not required. Planning and construction activities are affected by such a decision.

The objective is the detection of all potentially affected activities by an algorithm. These activities need to be revised. Some of these might become needless so that they can be deleted from the model. Some of these might be modified. New target values for the process need to be generated after the revision of the affected activities.

3.4 Documentation of subsequence modifications

It is required to document subsequent modifications. In general, subsequent modifications influence time and cost. The consequences of subsequent modifications need to be comprehensible. Different process models need to be compared automatically. Modifications need to be detected by an algorithm.

4 Graphs

Different graphs are introduced to achieve that the different types of subsequent modifications can be handled. A graph is defined in mathematics as a structure consisting of a set and a relation in that set. Three graphs are introduced, the process graph, the version graph and the binding graph. The three different graphs are defined in the following paragraphs.

The process elements and the relations between the process elements form the process graph. The process graph is set up during the specifications of the process elements and the relations between these elements. It results directly from user input.

The process elements and each relation between process elements are represented by objects. A new version of an object is instantiated if the user modifies an existing object. A relation is automatically instantiated between the original object and the modified one. All objects and the relations between modified objects form the version graph, Beer and Firmenich (2003) [3]. Objects are administrated in set. Relations between versions of sets are also stored in the version graph.

The binding graph results from interdependencies between objects if new objects are formed from existing objects, Pahl and Beucke (2000) [4]. The binding graph directly results from the modeling concept consisting of specified objects and computed objects as shown in figure 5.

5 Example

This section illustrates how the management of subsequent modification is done, based on a tiny example of a planning and construction process.

In a first step, the user specifies documents which need to be worked out. He decomposes the building into components. In a second step, the user specifies types that describe the process of working on documents and components; and he assigns these processes to the documents and the components. The third step covers the interdependencies between documents and components. The user specifies a table of contents for each document. An example is shown in Figure 6.

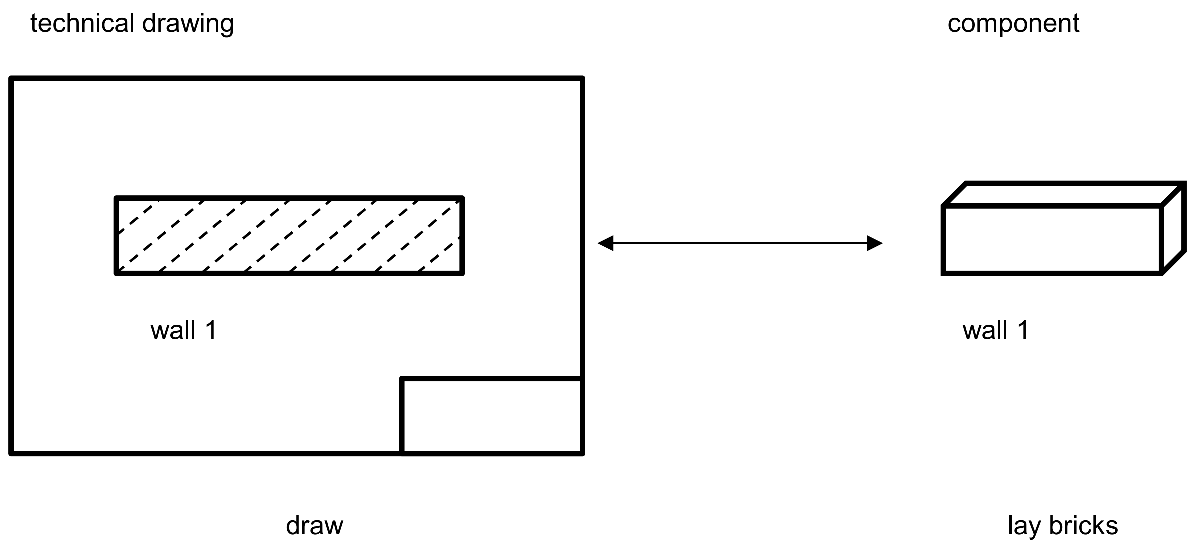

Figure 6: Interdependency between document and component

The result of a computation is a list of elementary activities for a planning and construction process. Now the user has to specify the additional prerequisites for elementary activities if required.

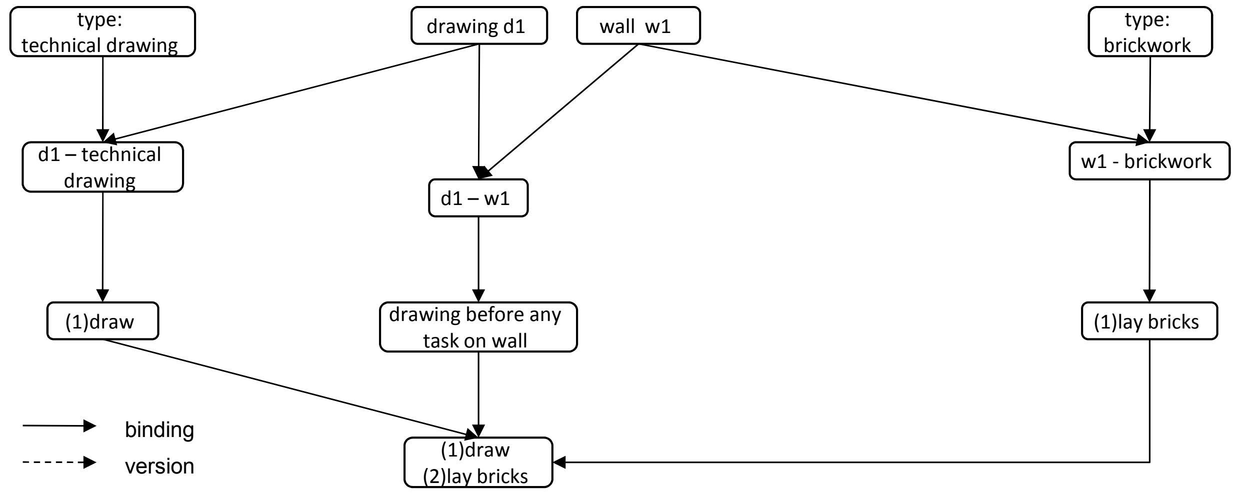

Figure 7: Process of Planning and Construction

A subsequent modification takes place. The material for wall w1 in the technical drawing is changed to reinforced concrete. A new version d2 is created as shown in figure 8.

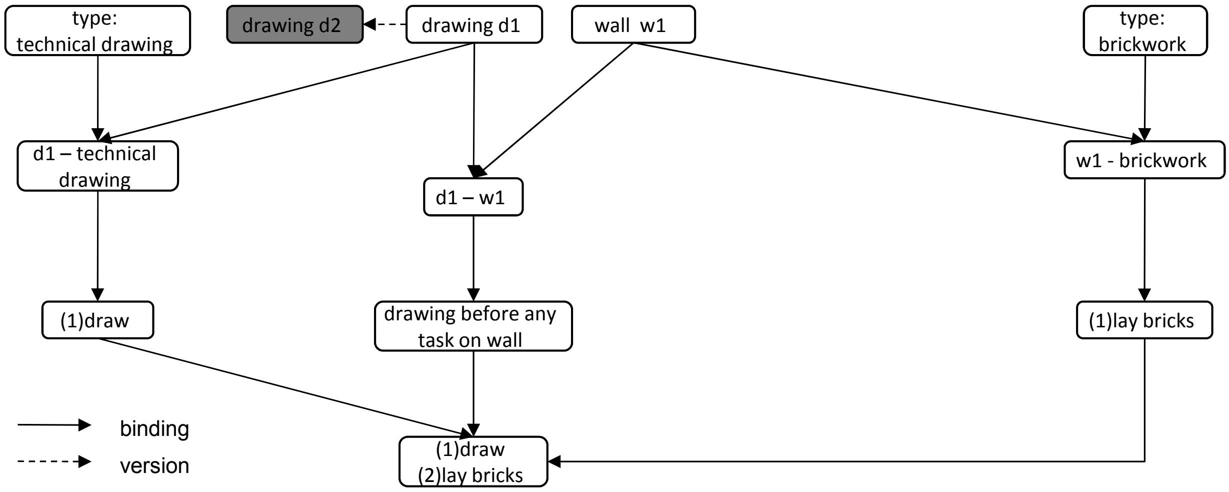

Figure 8: A new version of drawing worked out

The relation between drawing d1 and component wall w1 becomes obsolete. A new version is required as shown in figure 9.

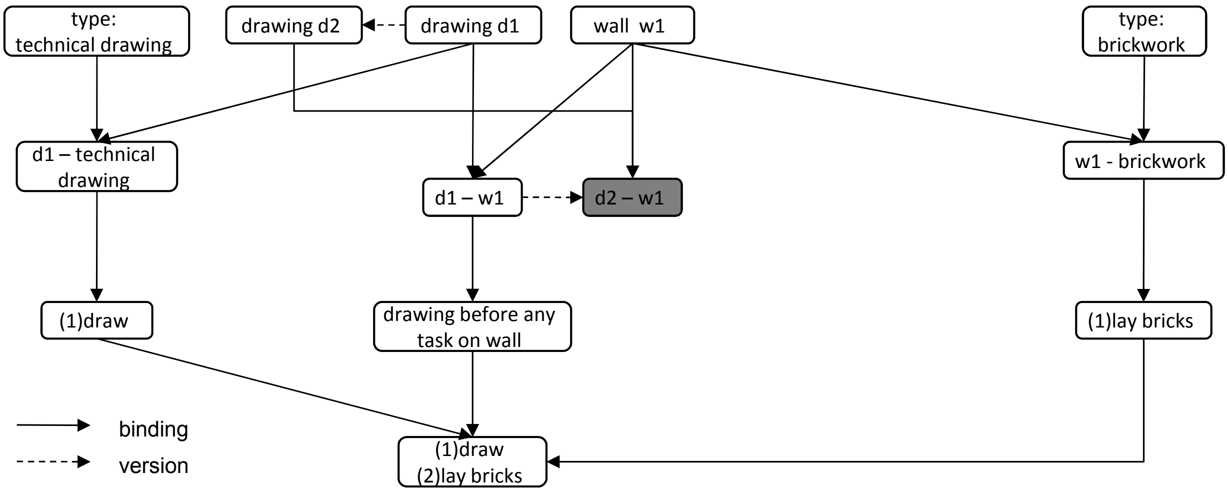

Figure 9: Affected relation becomes obsolete and a new version is reqired

As a consequence, "drawing before any task on wall" requires a new version as shown in figure 10.

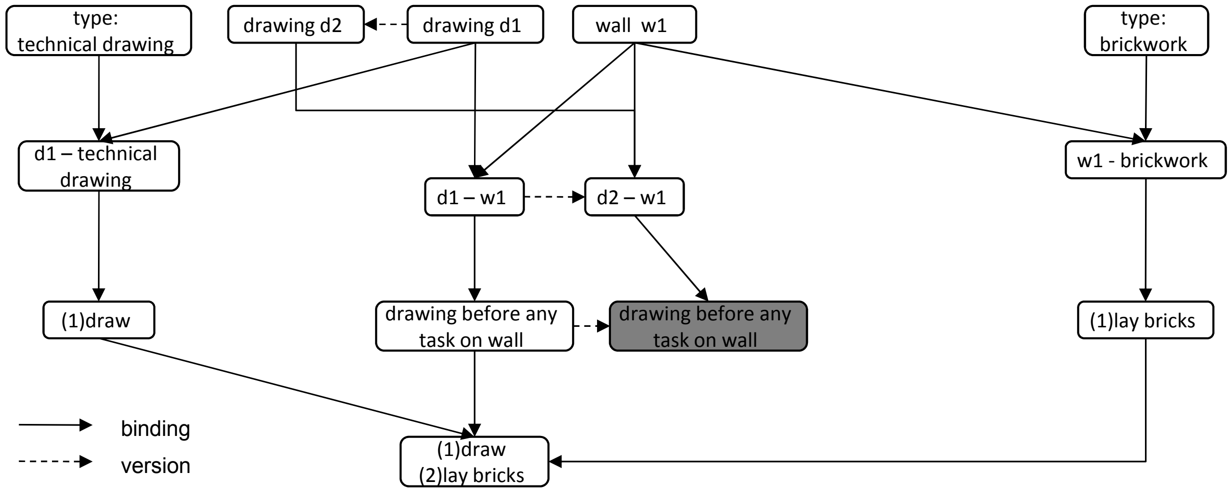

Figure 10: A new version of computation "drawing before any task on wall"

The interdependency between wall w1 in plan d1 is used to identify the affected component. The user has to decide whether the used type of the component is still valid. The material of wall w1 changed to reinforced concrete. It is necessary to select a type for reinforced concrete. Figure 11 shows the new version of component type and the new version of relation component – type.

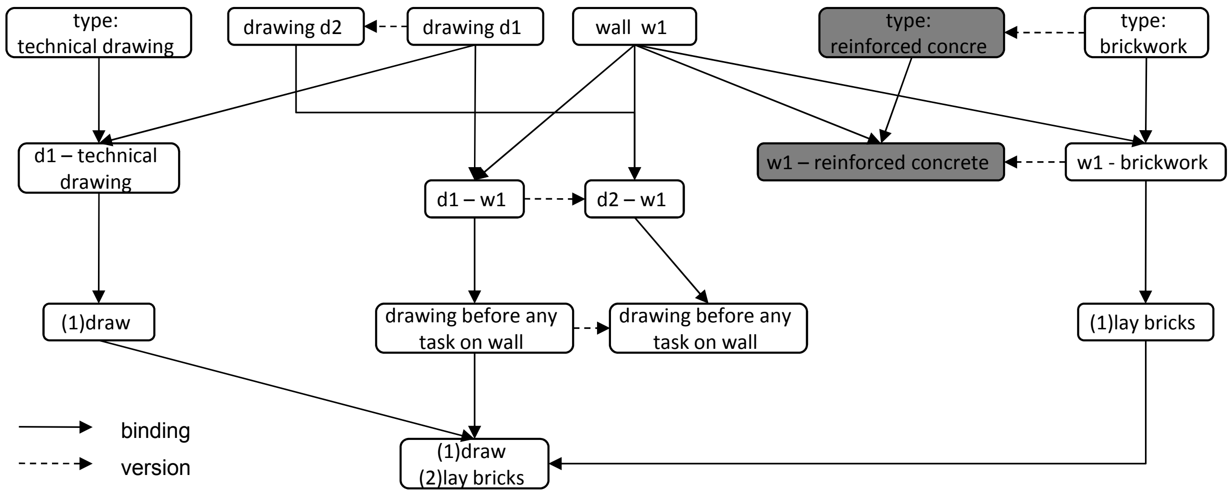

Figure 11: Component type becomes obsolete, a new version is required

The type reinforced concrete contains another sequence of task, so a new version of elementary activities is computed as shown in figure 12.

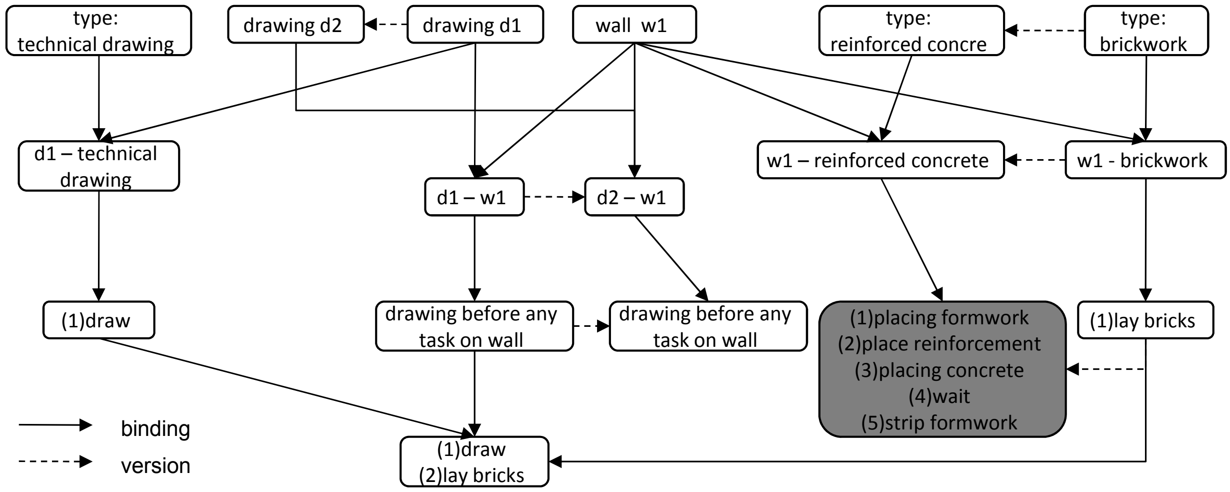

Figure 12: Another sequence of task because reinforced concrete type

The new version of construction tasks affects the version of the project task sequence. A new version is generated as shown in figure 13.

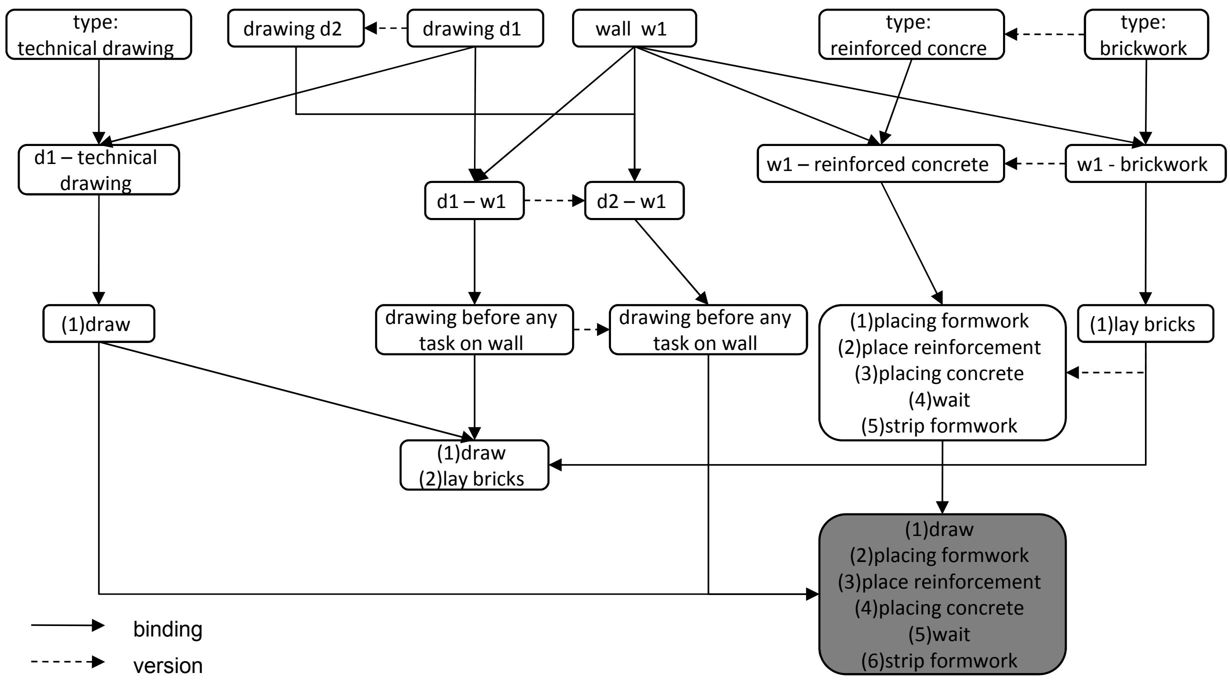

Figure 13: The new project task sequence

6 Conclusion and Outlook

The approach presented in this paper makes use of an existing modeling technique for construction processes. Different types of subsequent modifications can occur. To handle these different types, three graphs are used: the process graph, the version graph, and the binding graph. The process graph is used to track potentially affected activities. The version graph is used to compare modified process models. The binding graph is used to track effects if process elements become obsolete.

Some potentially affected elements can only be localized but the user has to decide whether the elements are up to date. Components are only assigned to a drawing, not to the elements of drawing. So each component has to be viewed individually.

The implementation of the concept presented is under progress. This research is also still under process because a suitable user interface is required to administrate all versions. It is still an unanswered question of how project managers can be convinced to modify their mode of working with respect to such formalized approaches.

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