FORMAL TREATMENT OF ADDITIONS IN PLANNING PROCESSES

Axel Klinger [1], Volker Berkhahn [2], and Markus König [3]

ABSTRACT

In building engineering every state of design, planning, construction and usage is characterized by specific processes. These processes can be organized very efficiently with the support of modern information and communication technology. Within the research project "Relational Process Modeling in Co-operative Building Planning" a process model is described by three parts: an organization structure with participants, a building structure with states and a process structure with activities. During the execution of planning processes unexpected problems may occur. Problems often lead to additions for the process. This paper presents methods for the formal treatment of additions in cooperative planning processes for further analysis and optimization purposes.

KEY WORDS

Process Modeling, Additions in Building Engineering, Co-operative Planning, Network-based Planning Environment.

INTRODUCTION

Within the research project that is granted by the German Research Foundation, a relational process model for planning processes was defined and the fundamental concept of the model was presented in (Damrath et al. 2002a) and (König et al. 2004b). This model consists of three hierarchical structures for the organization, the process and the building and corresponding relations between these structures. The model covers methods for analyzing structural consistency and correctness as well as methods for time scheduling and semi-automated communication by Petri nets. The treatment of additions requires the extension of consistency and correctness conditions of this relational process model that are described in this paper.

To guarantee the consistency of the process model, we have developed methods to insert additions in respect of structural consistency and correctness. If for example an inserted

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addition leads to a cycle on the lowest (most detailed) level of the process structure, the structure becomes inconsistent. On the other hand cycles may occur on upper (less detailed) levels of the process structure, if additions are inserted in the lowest level. This describes an iterative planning process. Other consistency conditions cover the marking and labeling for time scheduling and Petri net simulation. Additions can be used to analyze the quality of planning processes. Few or less extensive additions are indicators for a good planning process.

In order to create, control and analyze planning processes a prototypical application has been developed within the context of the research project. This application has been implemented for building planning in a network based environment. It also offers potential for other application areas due to its general approaches. These concepts and the implemented application are exemplary validated in a real building project.

RELATIONAL PROCESS MODELL

The process model that has been developed during the last years is subdivided into an organization structure, a building structure and a process structure. The organization structure covers the actors of the planning process, such as persons, companies and institutions and their roles in the planning process. The building structure covers the elements of a building, such as walls, slabs, rooms, floors etc. The process structure covers the activities and their transitions. These structures are connected by outer joints between their elements, so that an actor executes activities, an activity covers tasks for building elements and each task requires special roles from the organization structure. Within this paper we concentrate on the process structure.

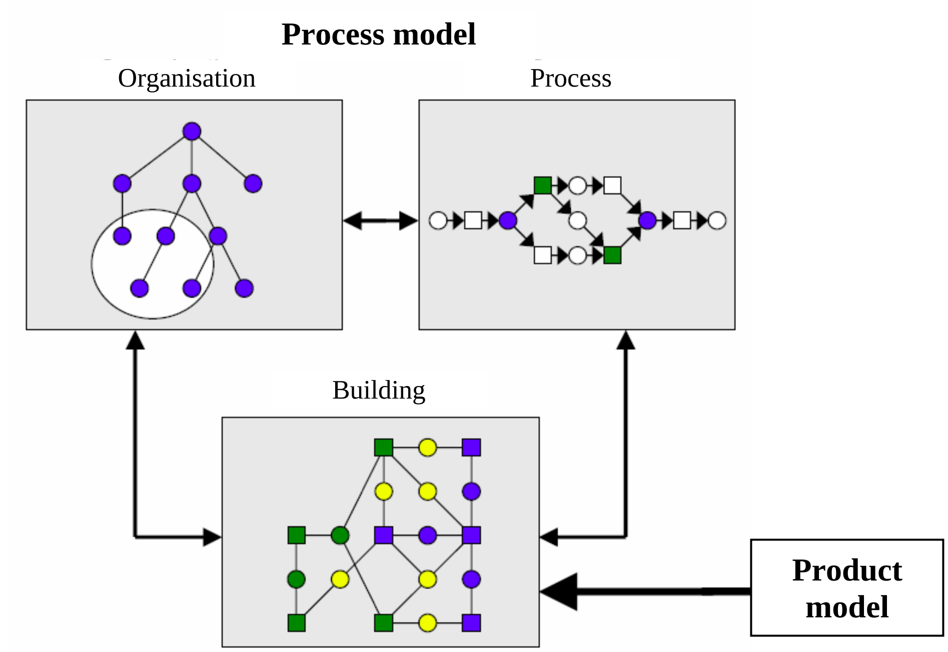

Figure 1: Relational process model with organisation, building and process structure

PROCESS STRUCTURE

The process structure is described by a hierarchical bipartite graph. The elements of this structure are activities and transitions. Each element of the structure can be decomposed separately into more detailed elements. There are no cycles within the lowest level of the structure but by composition to higher hierarchical levels cycles may appear. With no cycles on the lowest level the structure has at least one start and at least one end transition.

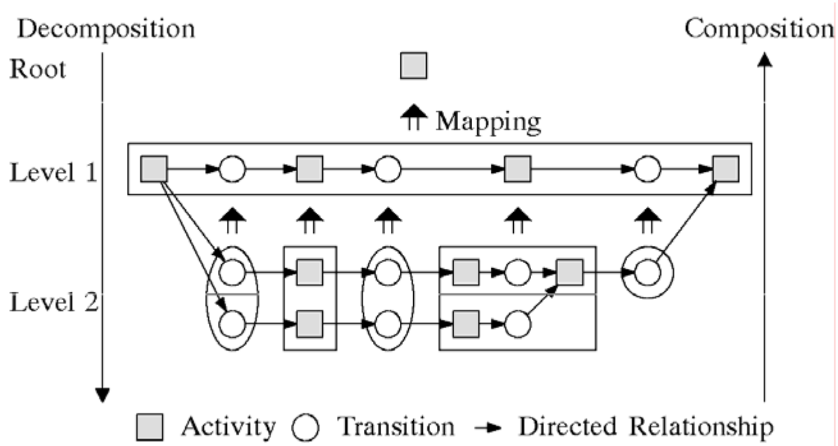

Figure 2: Hierarchical process structure

Based on simple Petri nets, the actual state of the hierarchical process structure is described by the marking of finished activities and actual transitions. Consistency conditions for the marking on different levels of the hierarchical structure are described by König (2004).

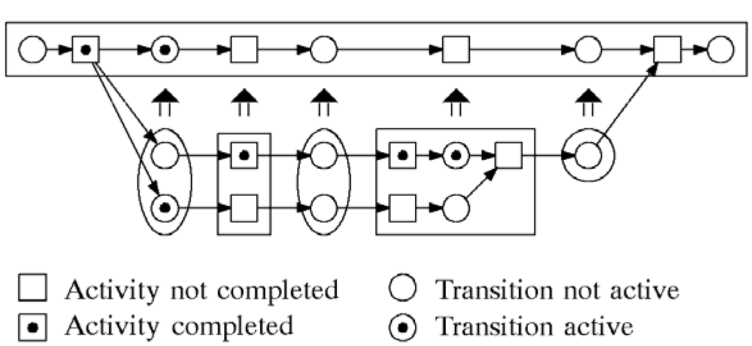

Figure 3: State of the hierarchical process structure

Critical path methods are used for time scheduling. They were transferred in generalized form to bipartite graphs. Activities are labeled with positive real time values for duration. Transitions are optional labeled with positive or negative real time values for time offset. The consideration of hierarchy requires additional consistency conditions (König 2004).

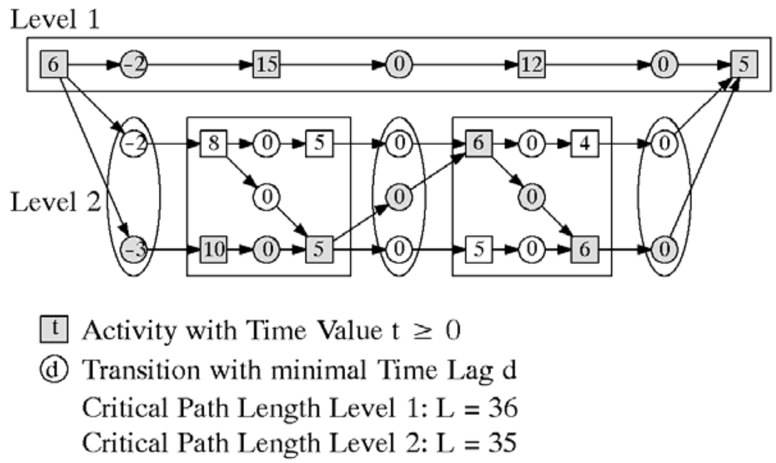

Figure 4: Critical paths in the hierarchical process structure

ADDITIONS

Additions in planning processes are activities that have to be executed in addition to the regular planned process. Additions are used to correct mistakes of the planning or execution process as well as for adding additional features by request of the owner of the building object. For optimization purposes we only concentrate on the first kind of additions in order to avoid mistakes in future planning processes.

Every addition is modeled as a set of special marked tasks within the building structure. These additional tasks lead to one or more additional activities in the process structure. This extension of the process structure has to be consistent.

Additions are ordinary activities and can be signed by a flag. As far as we use prefixes in the name attribute, we do not have to change our model in order to deal with additions. For the insertion of additions into a process, we need some methods to keep the structure consistent. These methods are shown in the next sections.

CONSISTENCY OF ADDITIONS

The consistency of additions has to be checked for the hierarchical structure, the marking and labeling of all new activities as well as the consistency in respect of contents for the hierarchical elements.

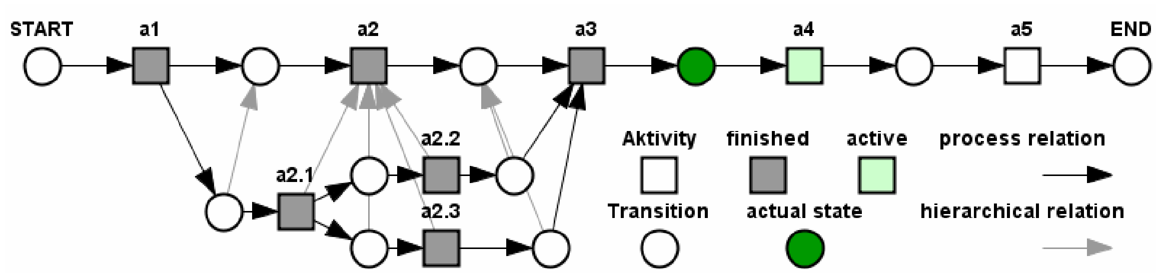

Figure 5: Planning process in approval planning phase

The actual state is shown in figure 5 by the marking of the transition between the activities a4 and a5. The activity a5 is running. During the execution of this activity an error is found in the results of finished activity a2.3. In order to fix this error an addition is inserted.

Usually if we insert a relation between two activities, a transition is inserted between them, connected by directed edges. If we jump back to an activity that has already been executed, we would close a cycle on the lowest level.

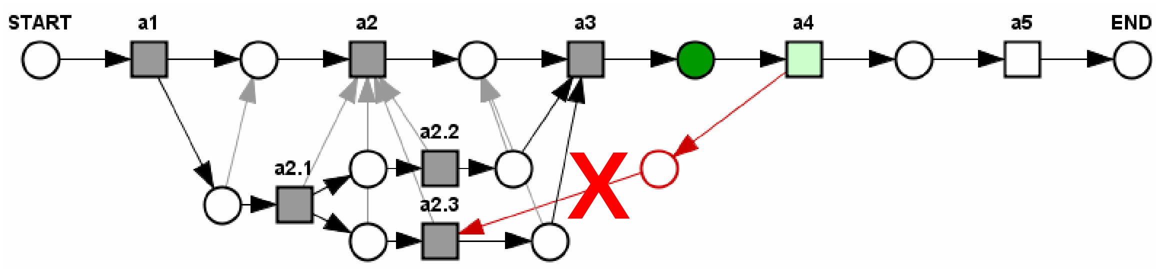

Figure 6: Jump back due to an error in a2.3.

Instead of closing a cycle, a new activity is inserted behind the erroneous activity as shown in figure 7. The new activity is the original addition.

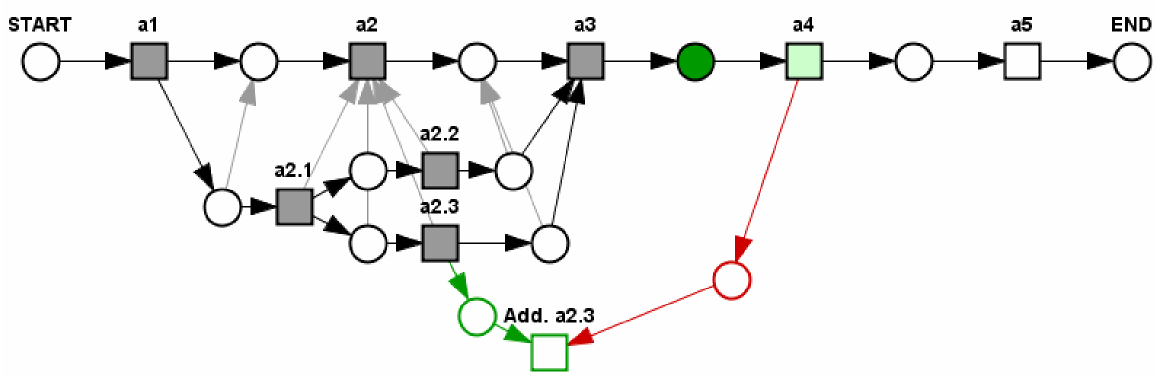

Figure 7: Inserting an addition

The structural consistency conditions require that the structure is acyclic with exactly one start and one end transition and every node lies on a path from start to end. In order to keep the structural consistency, all following activities of the erroneous activity also get additions as shown in the following figure.

These dependant additions can be found by a depth-first-search. We assume that additions are only necessary for terminated activities. Activities that did not start till now can still be edited. So we reduce the set of dependant activities to those who have not started by subtracting the not-started activities of the process from the dependant activities.

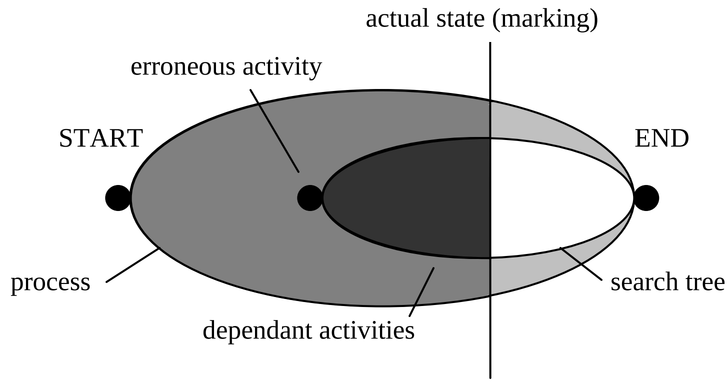

Figure 8: Dependant activities

At least all dependant running activities get additions too, in order to avoid cycles on the lowest level.

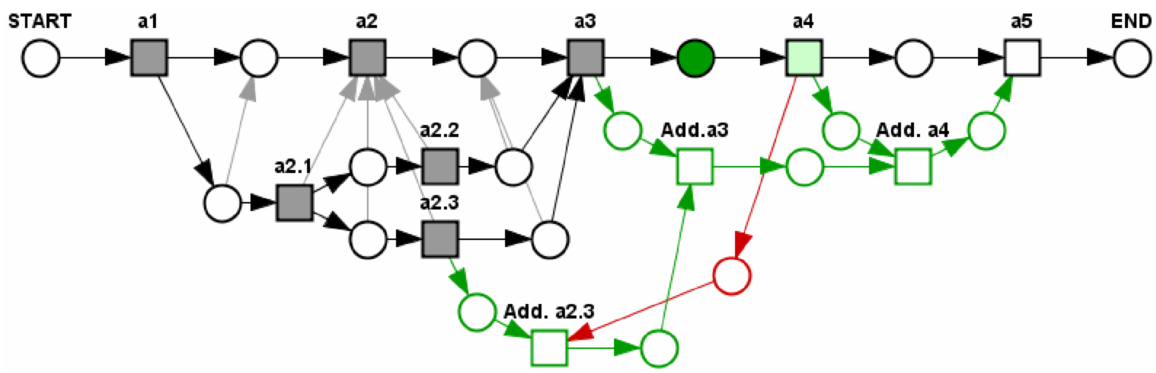

Figure 9: Inserting dependant additions

The hierarchical consistency conditions require that every node, except the root, has exactly one parent node. In order to keep the hierarchical consistency, all additions are attached to the same parents as their original nodes as shown in the following figure (links to the root are not plotted).

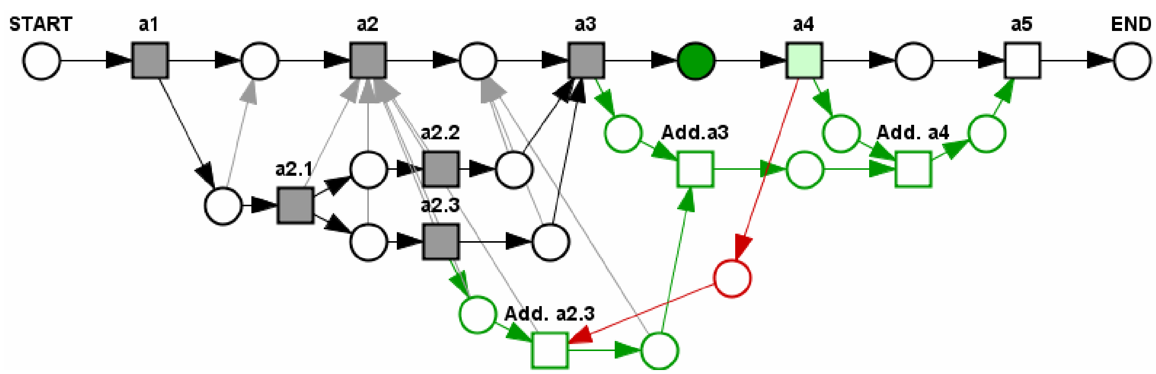

Figure 10: Structural and hierarchical consistency – inserting dependant additions

The marking of the process is consistent, if the original addition can start and all following additions can start if all predecessors are finished. In order to keep the marking consistent, transitions are marked between each addition and its original activity.

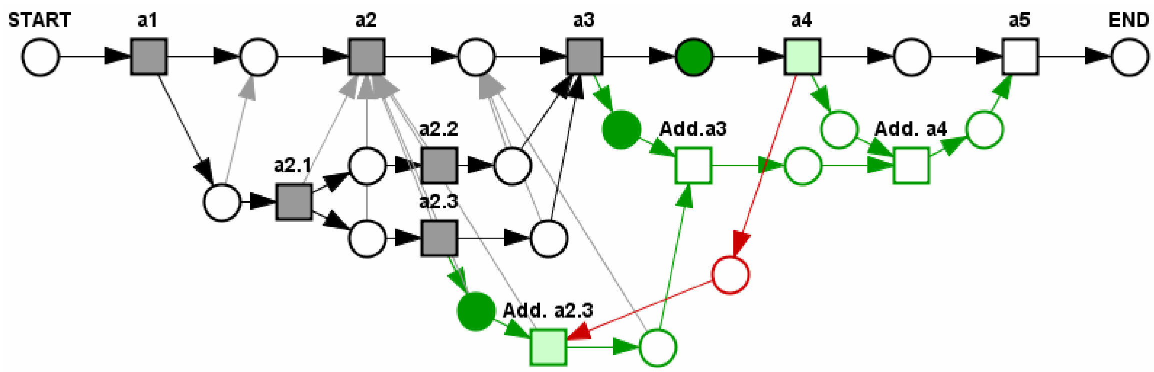

Figure 11: Consistency of the marking

The labeling of the process is consistent, if the critical path on a higher level is an upper bound for a critical path on a lower level. In order to keep the labeling consistent, the time values have to be updated for all compositions. If one of the additions lies on a critical path, the project will delay.

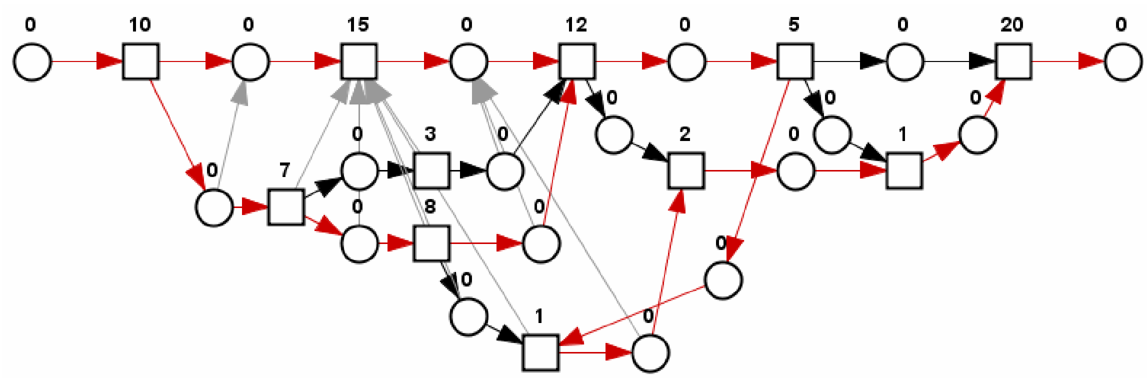

Figure 12: Consistency of the labeling and critical path

In this manner additions are inserted into the hierarchical marked and labeled process structure. The next step could be the optimization of these additions or the analysis for future projects. We will not step into the optimization, but will have look at some indicators for the quality of planning processes.

QUALITY OF THE PLANNING PROCESS

When additions are inserted into a planning process, the planning engineer has to minimize the delay for the project as far as the additions are on a critical path. This can be done for example, by using more resources or by splitting running activities into a basic activity and additions that can be executed separately.

Formal indicators for the quality of the planning process are the number of inserted additions, the number of all additions including dependant additions, the number of additions on a critical path and the number of cycles on upper levels as well as the total delay for the project.

- Number of additions for original erroneous activities
- Number of all additions including dependant additions
- Number of cycles on a higher level
- Total delay, if additions on a critical path

These formal indicators can be used for a benchmark for the quality of planning processes. The next figure shows an application screenshot of the prototypical implementation of our process modeling environment.

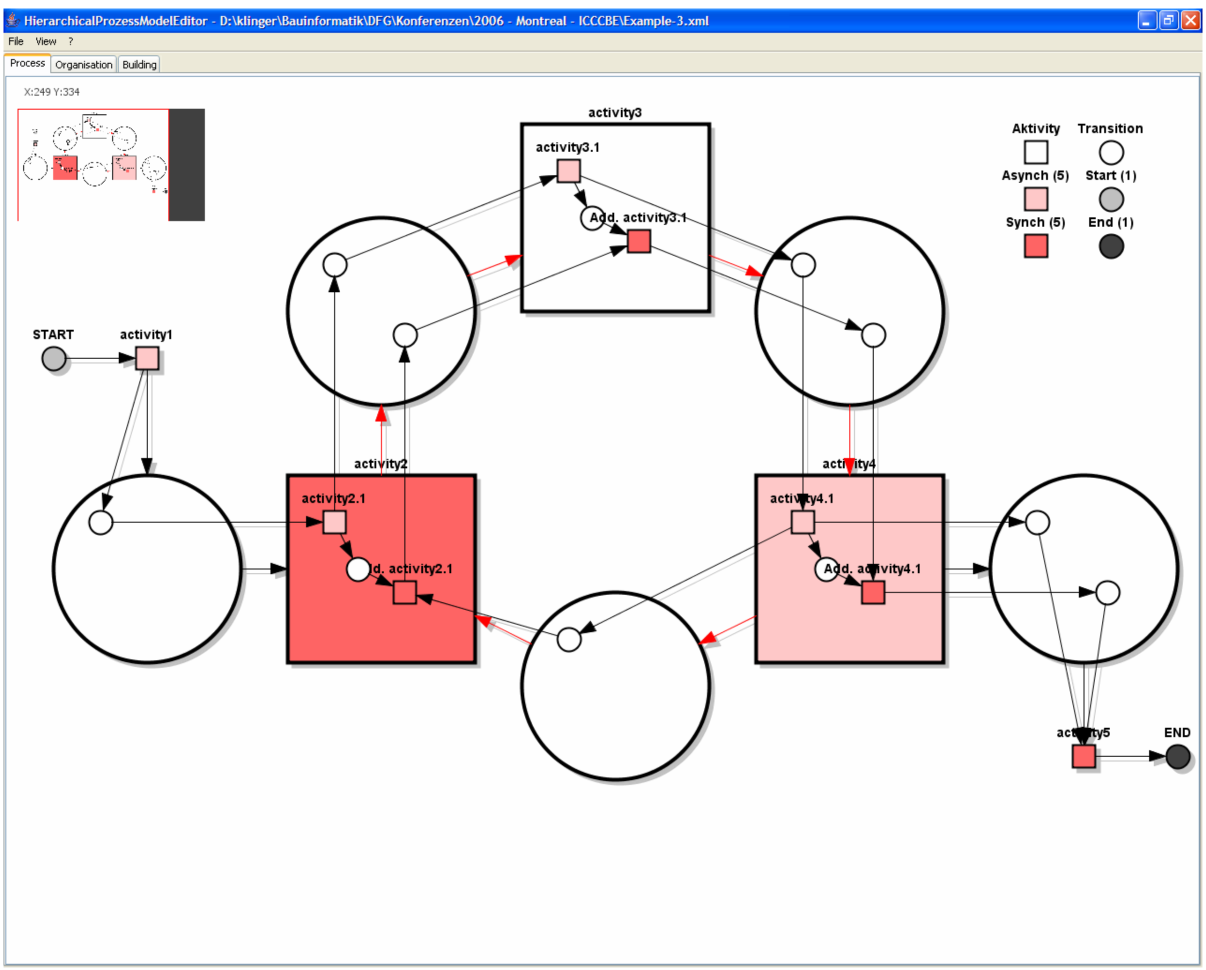

Figure 13: Application screenshot

CONCLUSIONS

In this paper a concept for treating additions in the relational process model is presented. For often discussed iteration processes in building planning we suggest to create new activities for a second step of an activity in order to avoid cycles on the lowest level of decomposition. This may lead in cycles on a higher level.

For the insertion of additions formal consistency conditions have been developed to keep the structural and hierarchical consistency as well as the consistency of the marking and labeling. The maximum influence of an addition for the process is taken into account up to the actual marking.

The analysis of additions provides a basis for optimizing planning processes for future projects. This concept has been implemented in a prototypical application.

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