MANAGEMENT AND EVALUATION OF ALTERNATIVE CONSTRUCTION TASKS

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ABSTRACT

Projects in civil engineering are commonly planned with only one possible construction schedule. Often it might be useful, if more than one could be investigated. But modeling alternatives is expensive and time extensive. This paper presents an approach for generating a construction schedule that includes various alternatives and their evaluations.. The schedule is calculated on the basis of logical dependencies between tasks. Thus, the schedule can be generated at any time. The developed approach aims at achieving a faster reaction, if problems occur at the construction site. Furthermore, it can be used for providing decision documentation. The model is based on mathematical concepts of set and graph theory. The formal description of the model provides a general, independent basis for corresponding software applications.

KEY WORDS

Computational management, process modeling, alternative construction tasks, decision support

INTRODUCTION

Construction processes in civil engineering are often very complex and contain many different tasks with various logical dependencies between them. Based on project specific dependencies exactly one time schedule is defined by conventional methods.. Different alternative tasks and sequences can be used to achieve the project objectives in a more flexible way. The project manager defines which of the alternative tasks in which particular sequence are to be carried out.. If changes or problems occur during the construction process, tasks and sequences have to be modified conventionally and alternative tasks and sequences have to be executed instead. This procedure is often very time consuming and expensive. As a result , the necessary modifications are often not carried out in reality. This leads to an information loss due to inconsistency between the planned schedule and the real situation at

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the construction site. For instance, it would be no longer possible to get realistic forecasts related to the project end.

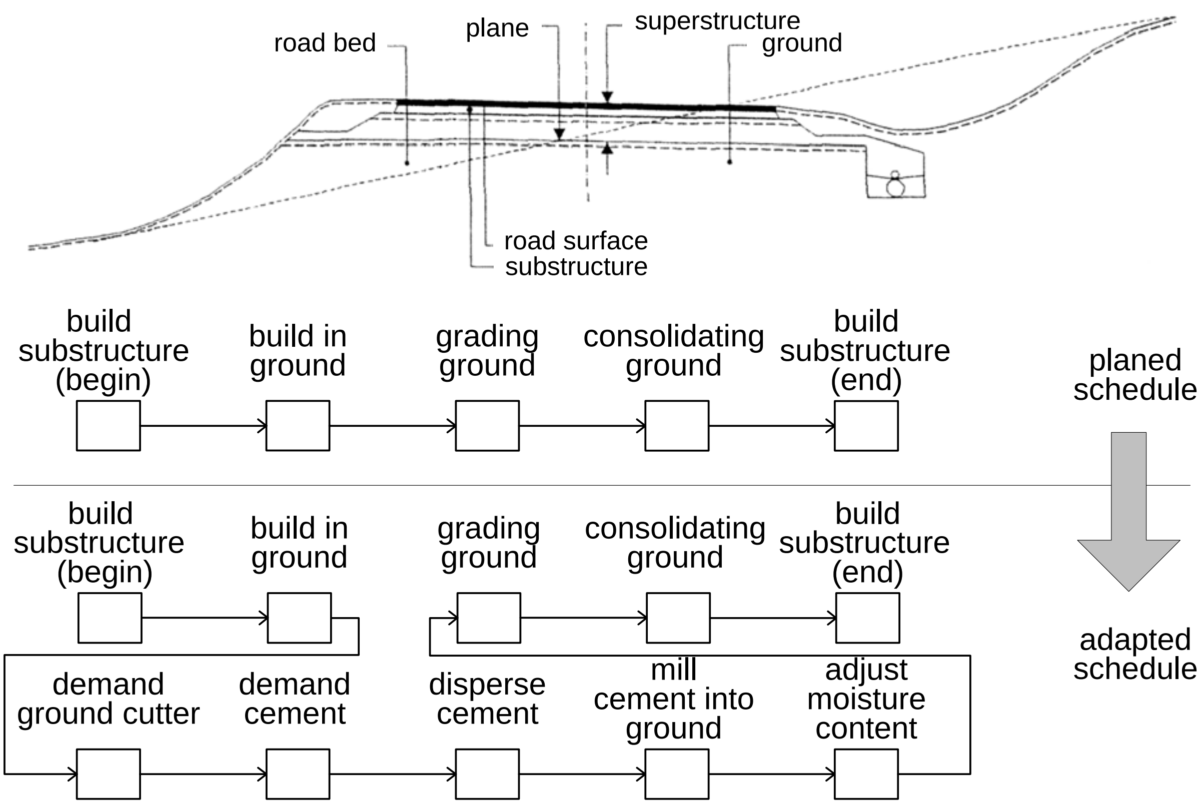

Figure 1: exchange of tasks because planed ground conditions differ from real ground conditions – rough description

Figure 1 shows a rough description of a typical situation in road construction.. The planned ground conditions turn out to differ from real conditions at the construction site. The bearing capacity of the ground is not given using the planned consolidation method. The defined schedule has to be adapted. Another construction alternative for preparing the ground becomes necessary. In this case the condition of the ground has to be improved using a hydraulic binder. Additional equipment like a ground cutter, cement and water is needed on site. The construction schedule no longer matches the real situation. Using current models, the construction schedule has to be adapted using time consuming methods. The approach presented within this paper allows to calculate construction alternatives in advance. The advantage of early consideration of alternative tasks provides the possibility of a faster reaction, if changes or problems during the construction process occur. In this case one of the already modeled alternative tasks or sequences of tasks can be used to respond to the influences previously mentioned.

On the other hand, the explained advantage of having more than one possible alternative leads to exerting more efforts in creating and maintaining the new model. This would turn the advantage immediately into a disadvantage. Therefore, developing new methods and algorithms becomes necessary in order to reduce these efforts down to a minimum acceptable for practical purposes.

GENERATING SCHEDULES

Current research approaches focus on the logical dependencies between construction tasks (e.g. Racky 2005, Holzer & Geyer 2005). Those approaches are based on describing single tasks with necessary input and output conditions, as shown in Figure 2 (e.g. Huhnt 2005, Enge 2005). Based on set- and graph theory, it is possible to generate simple construction schedules. Therefore, the set of tasks has to be investigated. Tasks that have equal input and output conditions, reflect directed dependencies between them. As a result, a directed graph can be generated. Tasks are modeled as nodes and dependencies are modeled as directed edges. The mentioned approaches are used to check the workflow consistency as well as to utilize topological sort algorithms to order graph information in a layered structure. Alternative construction tasks are not considered within this approach.

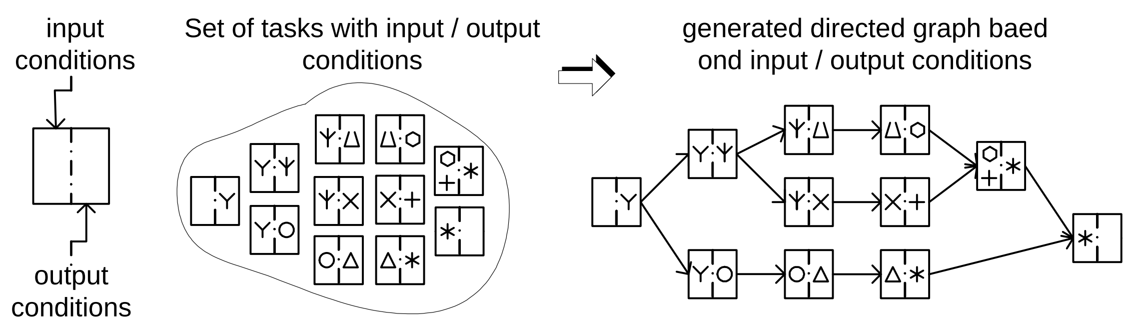

Figure 2: Describing tasks using input and output conditions and the generated directed graph – Specific symbols are used to despict different kinds of input and output conditions.

To make allowance for describing alternative construction tasks, there is a need to enhance the given methods. Simple directed graphs cannot be used to model alternative construction tasks. To model alternative tasks within a single mathematical model, it is necessary to transfer the simple directed graph into a bipartite or respectively into a workflow graph. This allows modeling decision situations as well as parallel tasks within workflows. Workflow graphs provide special node objects for executing tasks or sequences of tasks in parallel (AND-Split and AND-Join) or alternative (XOR-Split and XOR-Join) processes (e.g. van der Aalst 1998). As a first step, parallel or alternative sequences of tasks are identified within the generated directed graph, to do the transformation into the aimed workflow structure. The graphical representation is shown in the figure below:

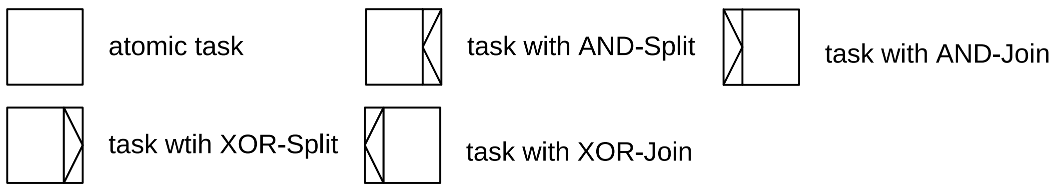

Figure 3: Graphical representation of workflow graph elements

IDENTIFICATION OF ALTERNATIVE & PARALLEL CONSTRUCTION TASKS

For identification and modeling of parallel or alternative sequences of tasks the input and output conditions are investigated. By means of logical patterns it is possible to recognize those sequences by operating on the directed graph from the previous section. The procedure of identification is carried out in four stages:

- Identification of alternative tasks results in detection of tasks with equal output conditions. Tasks identified this way are merged with an XOR-Join within the workflow graph.

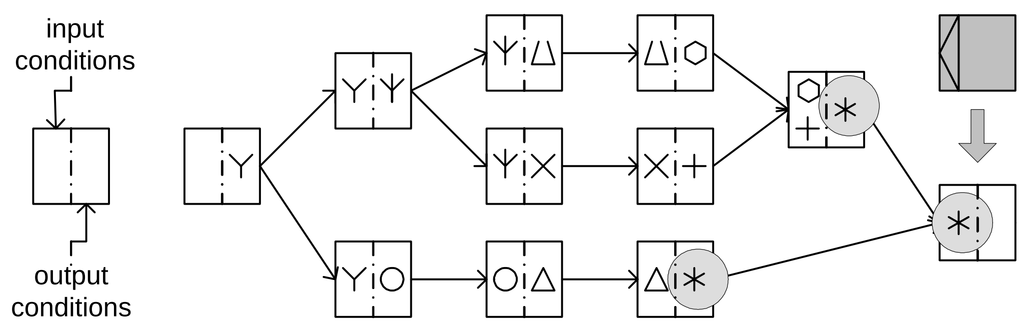

Figure 4: Identification of XOR-Joins

- The starting node of dependent alternative tasks is investigated by doing a backward search starting at the XOR-Join identified in the previous step. If paths that arise during the backward search are crossing, the begin of an alternative task sequence is found. In this manner identified nodes are marked as XOR-Split.

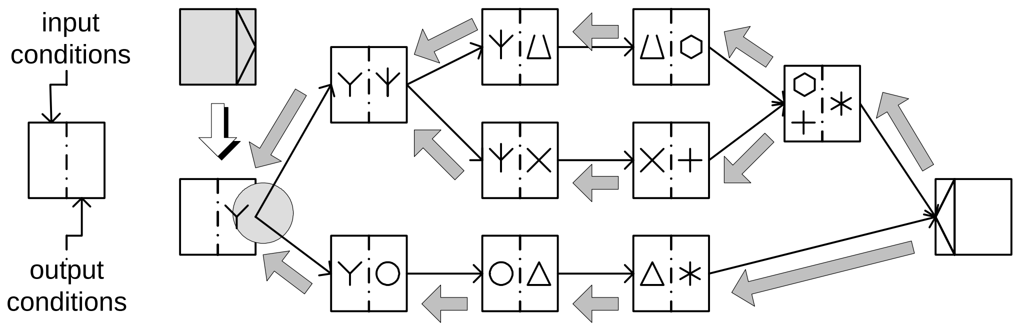

Figure 5: Identification of XOR-Splits

- Identifikation of parallel tasks is achieved by determination of tasks that possess more than one direct previous nodes. Then, if those tasks are not yet merged using an XOR-Join, these tasks have to be merged using an AND-Join. In that sense it is marked as a merging node of parallel tasks:

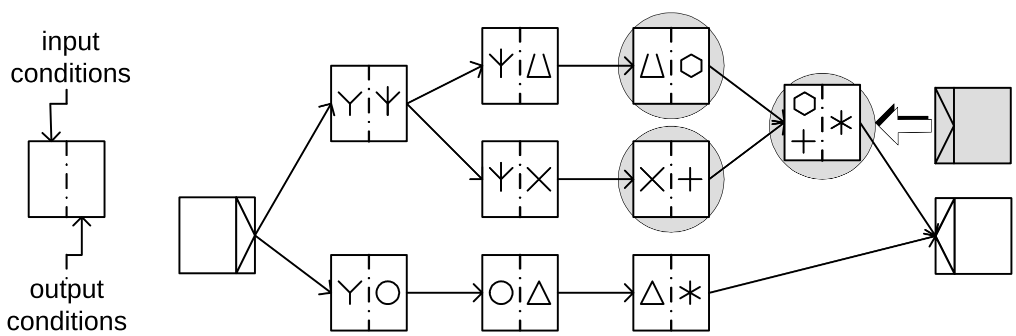

Figure 6: Identification of AND-Joins

- The last step identifies all tasks that have more than one successor and have not yet been marked as XOR-Split.Those taskes are marked as AND-Splits. This indicates a start node for parallel tasks:

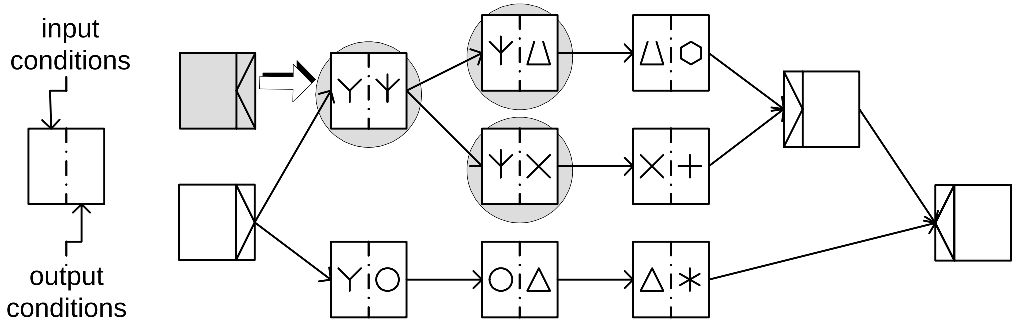

Figure 7: Identification of AND-Splits

At this state, the model provides the functionality for generating a workflow graph that contains alternative and parallel sequences of tasks. Those tasks have to be described using input and output conditions. Assuming that all necessary task descriptions are available for executing a certain project, it is possible to generate all probable options to accomplish the project goals – at any execution phase. Figure 8 shows the generated graph.

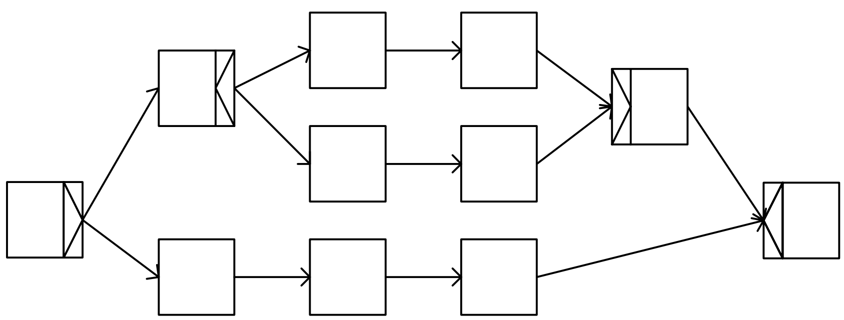

Figure 8: Generated Scheudle

EVALUATION AND DECISION SUPPORT

If the current project state reaches an XOR-Split within the workflow graph, a decision for one of the directly following sequences of tasks is inevitable. In general a decision is made based on two different approaches. On one hand, in practical projects it is often the project manager with his experience who directs the decision making process. On the other hand, constraints like time, money and other available resources play an important role in directing the decision making process.

Assuming the second case, a decision can be done using known methods from critical path analysis. Therefore, the workflow graph has to be weighted in terms of time, cost or resource evaluations. A critical path analysis leads to a single calculated construction schedule based on the chosen evaluations. The decision for one certain construction alternative can then be taken based on this calculation. Hence, corresponding decisions are comprehensible and reproducible at any time. Evaluations are introduced as discrete objects. A simple Evaluation Object consists of a value and its associated type as shown in Figure 9 below.

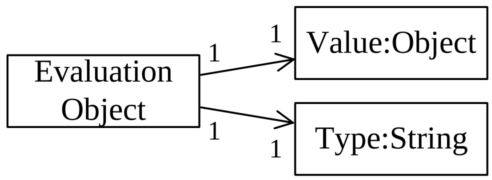

Figure 9: Class for Evaluation Objects

Each single task is related to an arbitrary number of Evaluation Objects. As a result, a weighted workflow graph can be generated for a certain type. Figure 10 shows the previously used sample schedule as weighted workflow graph using a cost type. Hence the graph is weighted and consequently the critical path can be calculated. For the example shown the bottom construction alternative was selected.

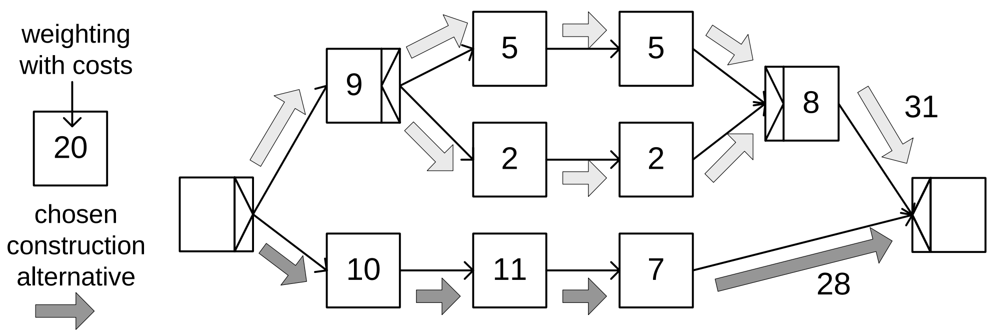

Figure 10: Weighted workflow graph with calculated critical path

To realize more complex evaluations like subjective experience of project managers the defined Evaluation Objects can be extended.

COMBINING CONSTRUCTION ALTERNATIVES

Theoretically it would be possible to model every way to build streets as well as other projects in civil engineering using the approach proposed. However, tasks are in common not freely combinable. Certain tasks imply assured previous tasks and vice versa.. In conclusion, alternative sequences of tasks are not freely combinable.. For example, if a foundation slab was planned and build for a determined load, it is technically not possible to execute an alternative that will exceed the slabs maximum rated load. This leads to the question if the shown approach may lead to inconsistent workflows.

Assuming that all defined tasks, especially their input and output conditions, are correctly defined, this approach will only lead to useful combinations of construction alternatives. Consequently the possibility of combining construction alternatives is given, if a path inside the graph from the start of a project beginning to the end exists. This may change at any project state. If an alternative was chosen, other construction alternatives will be ignored. It is caused as a result of not generating output conditions that are necessary as input conditions for other tasks.

However, it is possible that construction alternatives may co-exist, that are not combinable. A manual exclusion of combinations is supported by additional conditions. Those will be considered in further research activities.

CONCLUSION AND OUTLOOK

This paper presents a new approach for modeling construction schedules. It can be the basis for developing corresponding software solutions supporting civil engineers during the phase of planning and building construction. It aims on one hand to achieve a faster reaction if interferences during the practical execution occur. On the other hand it is possible to use well-known methods and algorithms for critical path analysis. This can be used to calculate a decision for one certain alternative or for an economical comparison of entire construction alternatives. With regards to the possibility of modeling alternative execution of building works combined with registering the "as-is state", it is also possible to codify such decisions as a project history.

The construction schedule itself is not static. The schedule can be calculated based on logical dependencies between the set of construction tasks. In this manner, the creation of well-defined tasks, including their input and output conditions, is of particular importance. Only accurately defined conditions will lead to construction schedules with logical correctness. Furthermore, this approach leads to a higher reusability of previously created schedules. The schedules can wholly or partially be integrated into new projects as a set of tasks. In the meantime, the efforts for modeling the schedule will be reduced.

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