Concept for a process model-based dynamic work preview in mechanized tunnelling

Fundamentals for developing a tool based on the Brenner Base Tunnel Construction Lot H41

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ABSTRACT: A workflow for generating a dynamic work preview is demonstrated based on the mechanical excavation in the main west tunnel of the Brenner Base Tunnel, construction lot H41. To create the work preview, a process model is used before the start of construction to determine where and when specific tasks are to be carried out. To account for deviations in the construction schedule during execution, a method was implemented that allows continuous updates to the work preview using data from site documentation. This approach gives the work preview a dynamic component, ensuring its relevance throughout the project.

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KEYWORDS: mechanized tunnelling, process modelling, work preview, Brenner Base Tunnel

1 INTRODUCTION

Traditional planning approaches in tunnel construction primarily focus on net excavation speed and often neglect the integration of logistics processes. Process simulation offers an alternative, holistic planning approach that enables the development of an optimal construction workflow; however, it has so far been used primarily in academic contexts. For practical implementation of this workflow during construction, a dynamic work preview is necessary.

The aim of this master's thesis is to develop a concept for a dynamic work preview in mechanized tunnelling. This work preview represents the target process specifying the tasks to be performed, including their start and end times and durations over the period considered. This will enable more precise and reliable planning of daily work processes, which will in turn increase productivity. To ensure a realistic outlook in the event of deviations from the original plan, the work preview must be continuously updated with actual execution data.

2 MAIN BODY

This master's thesis is based on a literature review focusing on mechanized tunnelling, process management, and process modelling. Additionally, project documents were provided, and two site visits to the Brenner Base Tunnel construction lot H41 "Sillschlucht – Pfons" were conducted, including a viewing of the single-shield tunnel boring machine in the main west tunnel.

2.1 Process model

The goal of creating the process model is to represent the relevant subprocesses (i.e., task) of the production and logistics process in such a way that the ideal sequence of tasks can be derived for the dynamic work preview. As part of the process analysis, the following information necessary for modelling is developed:

- To classify the activity within the overall process, it must be determined whether it lies on the critical path or is considered a secondary activity. Additionally, a predecessor must be specified, or, for secondary activities, the parallel activity on the critical path.
- For activities with a fixed duration, the time value should be specified; otherwise, a formula for calculating the variable duration must be provided.
- To determine the frequency of an activity, the recurrence interval should be specified, distinguishing between time-dependent and location-dependent activities.

2.2 Work preview

The development of the tool for the dynamic work preview was carried out in three steps. Initially, the desired functionalities and requirements were discussed and defined in conversations with employees in the Unit of Construction Management and Tunnelling. Next, an initial concept was implemented in Microsoft® Excel®, before the comprehensive development was completed using the Python programming language within the Jupyter Notebook web application.

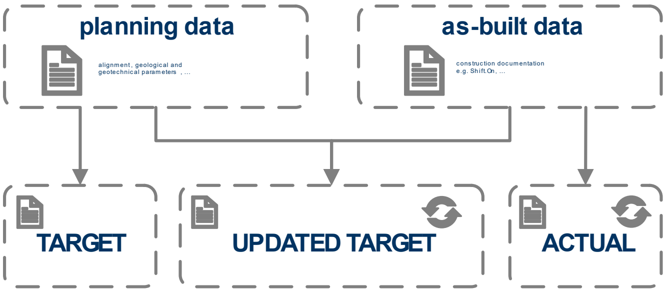

Fig. 1.1: schematic concept of the tool

The functionality of the developed tool is explained with the help of Fig. 2.1:

Before the start of execution, an initial work preview, the TARGET, is generated based on the planning data. For this generation, not only the information on tasks from the process model is required, but also the geological and geotechnical parameters, the mechanical and logistical specifications, and the excavation start time. This information is collected in an .xlsx file and subsequently imported into Jupyter Notebook. In the following task assignment, it is determined for each stroke which location-dependent tasks need to be performed at each stroke. Based on the durations of the subprocesses and the excavation start time, the start and end times of these tasks are then determined, before iteratively integrating time-dependent tasks in the next step. The result is a tabular schedule specifying the start and end times of each task to be performed. Visually, the schedule can be output as a bar chart for any desired observation period.

As mentioned initially, construction documentation data during execution is used both to update the work preview and to compare the TARGET and ACTUAL states, serving as a basis for process optimization. Execution data is exported as an .xlsx file in the form of shift logs from the Shift.On add-on of the data analysis software "Herrenknecht.Connected" and imported into the script. After preparing the data, it is visualized in a similar way to the TARGET, making it available for comparison. To determine the UPDATED TARGET in the next step, the information from the shift logs must be transformed into the structure of the task assignment. Here, it is determined which tasks were actually performed at each stroke. This task assignment is stored in an archive (exported .xlsx file), making it retrievable at a later time.

Based on the task assignment derived from the as-built data, the work preview can be recalculated. For each location-dependent subprocess, it is determined at which stroke number a task last occurred, and based on this, a task assignment is created for the remaining tunnel section. Similar to the TARGET, the schedule of the location-dependent subprocesses is determined before iteratively implementing the time-dependent tasks. The result can also be output in tabular form or as a bar chart for a defined observation period. This update of the TARGET to the so-called TARGETED can be repeated at any interval, as long as new execution data is available.

3 CONCLUSION

It has been demonstrated that the requirements defined for the tool within the scope of this master's thesis have been met, and the necessary information for generating a dynamic work preview has been successfully extracted. The developed Python script is capable of creating a dynamic work preview that accurately displays the generated data. However, for the desired observation period, the output is currently in the form of a static image, from which the precise start and end times, or durations, of the activities cannot be directly extracted. To obtain this information, the generated dataset must be opened. Additionally, if a preview for a different period is required, the script must be executed again after modifying the input.

From the author's perspective, the developed tool can be regarded as a preliminary draft or proof of concept. The design effectively demonstrates the basic functionality of the concept, but further optimization is necessary in terms of programming efficiency, as well as in the interactive and user-friendly presentation of the results.

4 OUTLOOK

A key potential for improvement lies in the scalability of the model, as it has so far been limited to project-specific machine and logistics designs. Future studies should therefore focus on expanding the framework conditions in order to make the tool flexible enough to be used for different construction projects. It is also recommended to increase user-friendliness, for example through an intuitive user interface that enables easier data input and reduces manual script execution. Further potential for improvement lies in the use of interactive visualisation tools, such as Microsoft Power BI, which could significantly increase the utility value of the tool through a dashboard. With regard to practical use, it is suggested that interruptions, for example due to holidays or other working time models, should be taken into account in order to generate more realistic schedules. In addition, it is proposed to automate the collection of actual data through the use of objective sensor data in order to increase accuracy and efficiency.

In the planning phase, a data-driven analysis of completed projects could contribute to the optimization of future processes. Furthermore, it is recommended to incorporate various penetration prediction models, allowing for the selection of the most suitable model for each project, thereby enabling more accurate forecasts. Additionally, the introduction of a conflict detection function is advised to identify potential overlaps early in the process. Moreover, the allocation of resources should be considered to facilitate more precise analyses of personnel and material requirements, as well as to optimize logistics planning.

5 REFERNECES

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