Concept for Tunnel Information Modelling based work-preview and documentation during construction at Tunnel Angath

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ABSTRACT: For the realisation of the ÖBB project Tunnel Angath, the idea was developed to use BIM for various controlling purposes. This publication takes a closer look at the implementation for the areas of work preview and documentation. Derived from established methods of conventional tunnel construction, the necessary models and their data requirements are defined. These include a target model based on the tender, several evolutions of work-preview models as well as singular as-built models, representing each excavation round. All models combined allow for a full documentation of the construction processes and its complete history. The accompanying data structure offers automated dependencies and future-proof expansion capabilities. Finally, this paper presents a concept, which still needs to be proven feasible within the pilot project.

Keywords: Tunnel Information Modelling, TIM, Building Information Modelling, BIM, Tunnelling, Digitalisation.

1 INTRODUCTION

Building Information Modelling (BIM) in the field of tunnelling – Tunnel Information Modelling (TIM) – has turned from a trend to a method requested by the construction industry and is currently pushing into all life cycle phases and disciplines of tunnelling. The construction phase is currently underrepresented, but holds high potential to generate many advantages by implementing BIM methods. So far, very few documented efforts exist. Single aspects of TIM in the construction phase are, for example, described in (Baraibar et al., 2022), where BIM was used for special use-cases within the execution of a tunnelling project, or (Hegemann et al., 2020), showing a BIM-based as-built documentation of segmental lining rings. On a larger scale, the general benefits of implementing BIM in infrastructure projects are shown by (Massimo-Kaiser et al., 2022).

The BIM pilot-project of the Austrian Federal Railways (ÖBB) for the construction of the Tunnel Angath generated the requirement to further develop BIM into a controlling tool for the client. This paper therefore takes a closer look at the challenges of handling work previews and construction documentation with TIM, exemplified by a conventional tunnel project.

2 SCOPE

The scope and goal for the successful development of a BIM-supported work-preview and documentation of the construction process were defined in coordination with the client. This was done during the tendering phase, with the possibility of applying, testing and adapting the developed concept in the course of the execution of the Tunnel Angath in the sense of the BIM pilot project and the alliance according to the resulting requirements. A workflow is to be developed in order to handle these steps within the current possibilities of modelling and data management. The overall objective is the continuous and consistent documentation of all construction activities and construction-related services as well as their interconnection. Based on this information, the work-previews are verified and adapted if necessary. All this information will then be used to perform target-actual comparisons.

Working within the construction phase of a tunnelling project, it was further defined, that a parametrically constructed tender- and target-model are considered to be given. A possible approach for a model-based tunnel framework plan is described in (Massimo-Kaiser et al., 2023). Due to the project-specific approach, it is further necessary that current Austrian standards are considered. The most relevant standards therefor are the

- Guideline for the Geotechnical Design of Underground Structures with Conventional Excavation (Österreichische Gesellschaft für Geomechanik, 2021)
- DAUB recommendations for BIM in Tunnelling and its five sub-parts (Deutscher Ausschuss für unterirdisches Bauen e. V., 2019)
- Applicable Austrian standards, e.g. B-2203-1 Untertagebauarbeiten – Werkvertragsnorm (Austrian Standards International, 2001).

The client therefore wants a tool to analyse and monitor the ongoing construction and derive certain project key performance indicators (KPI's) from the model. It is the goal to provide a solution for the use-case of BIM for controlling.

3 CONCEPT FOR TIM BASED WORK-PREVIEW AND DOCUMENTATION

In order to demonstrate a concept for TIM-based work-preview and documentation for conventional tunnelling, a two-step development process was completed. First, the necessary models were derived from the current workflow to create a work-preview and document the tunnel-advance. Based on these models, their individual requirements regarding data structure were developed in a second step.

Figure 1 shows the current workflow and the necessary derived models. Starting with the tender design and the accompanying tender model, the first step before construction starts involves the execution design. The resulting model forms the target-model for the controlling process. Then, construction can commence and the cyclical part of the process from Figure 1 starts. The first current work preview is solely based on the target model. Next, the excavation rounds commence, as does the need for documentation. This means that first as-built models are created in order to allow for full documentation. Based on new information from the documented excavation round, it is decided whether the excavation and support need to be adapted or not. If not, the work preview is updated on the basis of the target model and the cycle starts again. If it needs adapting, the work preview has to be worked on and once again go through an approval process, before the construction workflow is adapted and updated. For this concept, it is not further described how, for example, a construction and cost schedule can automatically be derived from the current work-preview and the target model.

When visualised over time, the models go through a development as presented in Figure 2. The target model is untouched. The work-preview model evolves over time and is either updated from the target model or changed with each excavation round and its accompanying knowledge gain. Finally, the sum of the individual as-built models, used for documentation, forms the overall as-built model. To facilitate easy target-actual comparisons, weekly, monthly and quarterly summaries of the as-built models are also provided.

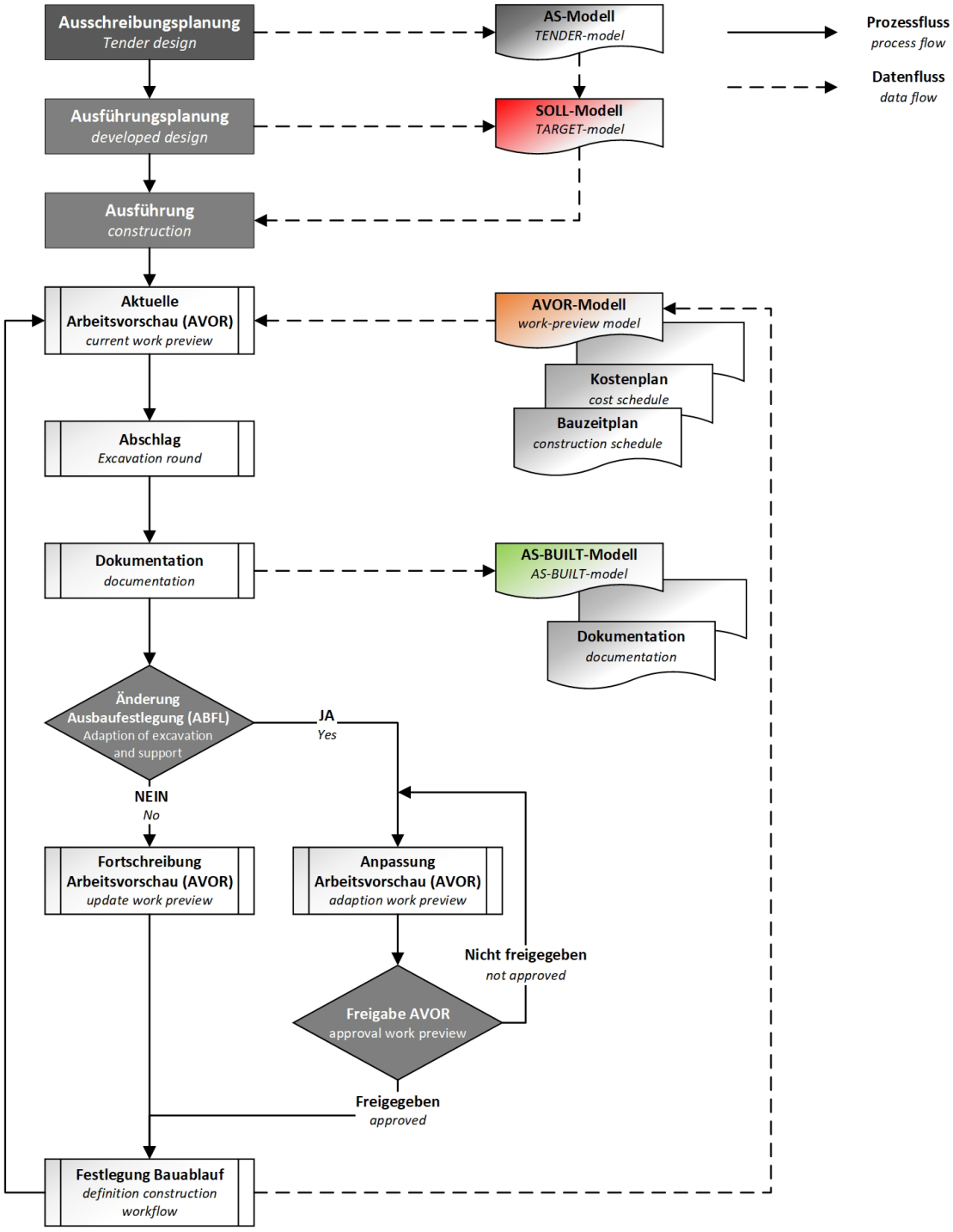

Figure 1. Schematic process of model-based documentation and work preview within conventional tunnelling.

As for the required data structure for each of these models, the minimum information need was identified regardless of the software to be used. These specifications are project- and client-specific and have to be further worked on within the alliance as soon as it is clear which tools will be used. For other projects and/or clients, however, this represents an effective starting point.

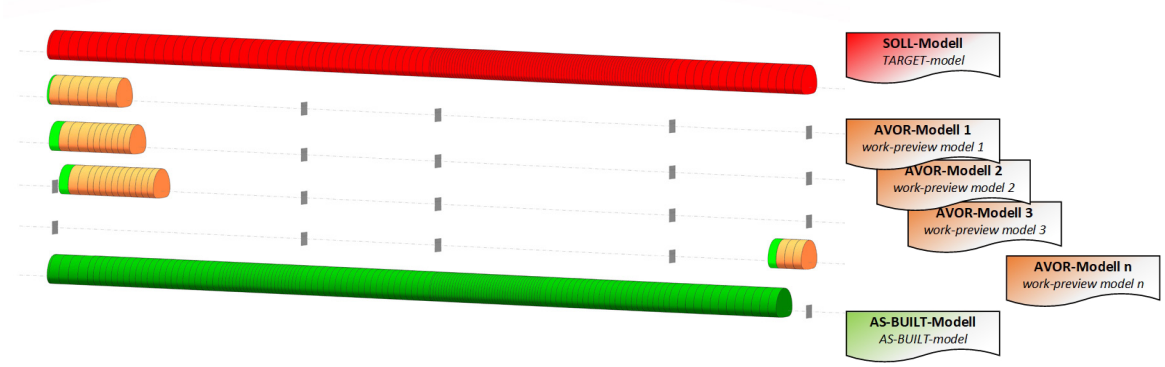

Figure 2. Development of models over time.

3.1 Target model

The target model, built during execution design, requires information on the geology and the tunnel structure. Based on the information from the tender-model, it needs a more detailed geometry of the tunnel, which has to be divided into sections corresponding with the planned excavation round lengths and includes the necessary geological information. This allows element-based mapping of the information on the tunnelling classes and work section in the bill of quantities as well as the cost information based on the tender and the scheduling done by the design team.

3.2 Work-preview model

These models are a further development of the originating target model, split into excavation rounds for work-preview. This allows for the storage of data records for the services to be provided. These cover a property-set (PSET) for the work section in the bill of quantities and one each for the construction schedule and the costs on the level of performance. For this phase, the model has to allow for an approval process by the necessary stakeholders within the project.

3.3 As-built model

In order to be able to include the necessary information, as-built models have to be based on the real geometry of each excavation round. The focus is on documenting the provided services and the execution of the works, including geology, 3D scanning and monitoring. They further have to include the work section in the bill of quantities and obtain approval thereof from a responsible person. The PSETs for construction schedule and costs now have to include the actual values.

3.4 Implementation Tunnel Angath

As mentioned, the developed concept is developed in preparation for the construction of the BIM and alliance pilot project Tunnel Angath. The endurance test will come with the actual implementation and daily use within the ongoing project and in accordance with the requirements of the alliance. In advance, however, a number of boundary conditions for the data structure have been defined. This is shown in Figure 3, resembling the TIM-model at any point in the course of project execution. The red segments only exist within the tender-/target-model. Ahead of the advance, the current work preview covering a predefined time span or stretch of tunnel is shown in orange. The green segments represent the excavation rounds, which have already been documented with as-built models. The lighter green segment in between is the excavation round that is just being documented at this point in time.

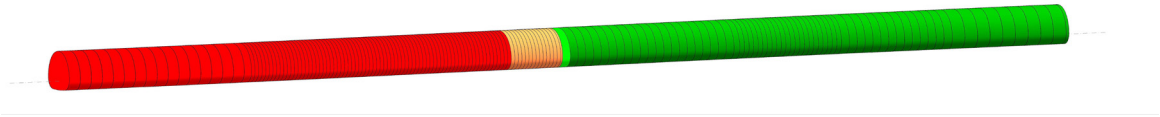

Figure 3. Reflection of the model at any point in time during project execution.

4 DISCUSSION

The developed concept comes with certain advantages and disadvantages, and has huge potential for future developments and extensions.

One major advantage is the comprehensive documentation of the full construction process within one system. The extra work resulting from the continuous model adaptation is less costly than the efforts to find documents and information during construction and especially in all situations following this phase. The concept also allows for possible adaptions of current workflows towards daily updates of the work-preview by automating the model generation and implementing automatic dependencies within the semantic data. This would be an advance over the current situation, made possible by the automation of model creation and the efficient use of the implemented digital information. Another major advantage is the documented history of the construction processes. Being able to look back at the different developments of the work-preview models allows for the comprehensibility of all construction-related decisions.

Currently, there are disadvantages that can be identified. At the moment, for efficiency reasons, the different evolutions of the models are created as new models rather than adapting the existing ones. Being able to adapt the models while still having an explicit reference to the target situation would allow for even easier data-storage throughout the whole construction process. For now, the combination of various models still does the job efficiently enough. Also, any deviation of the work-preview that lies outside of everything the target-model covers will need a lot of extra work to be implemented in the model and the data structure. With further development of software-tools, templates and standards, this issue will soon resolve itself.

Next steps of the concept have to take a close look at the possibilities of automatically creating a construction and cost schedule, based on the target model at first and later on the evolving work-preview models as well as the as-built models. It should also be looked into further possibilities for usage within project-controlling, i.e., post-calculation, resource planning, or reports, to name just a few. As the Tunnel Angath is being realised with an alliance contract, this could also be an interesting approach to find solutions tailored to this specific framework.

5 CONCLUSION

This paper presents a concept for the usage of BIM within the construction phase of a tunnelling project for controlling purposes. The use-case was defined by the client to cover the work-preview as well as documentation on a model basis. With the presented concept, four phases of the actual model are defined, including the tender-, target-, work-preview- and as-built model. The work-preview model can thereby go through a number of evolutions, always adapting to newly gathered information. Equally important is the development of appropriate data structures, which, on the one hand, enable automated adaptations and further developments of the model. On the other hand, they should enable simple and targeted evaluations of target-actual comparisons at the desired time intervals. The basic idea for an implementation within the Tunnel Angath was shown, but only comprehensive testing under real life conditions can show if the concept can be used as intended. With the beginning of the execution phase (02/2023), the presented concept is currently being implemented and evaluated in the planned BIM process within the alliance, taking into account the available software.

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