Project management in connection with a digital construction site with BIM in tunneling

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ABSTRACT: The special features of tunneling create great potential for utilizing the advantages of the digital construction site and the BIM method during construction. The approach was applied to the execution of an approximately 600 m long road tunnel for mining excavation. Data sources, such as the digital tunneling documentation, were combined in a central live data management system and used efficiently, especially for project controlling and risk management. In addition to an As-planned model, an As-Built model was created during construction implementation on the basis of the digital construction site data. Each volume based calculation of time (4D) and costs (5D) conducted for the project was in accordance with the construction contract guidelines and specifications. These calculations formed the basis for checking monthly invoicing, performing precise target/actual comparisons and transparently presenting forecasts.

Keywords: Digital Construction Site, BIM, Tunneling, Project Controlling, Monitoring Dashboard, Data Management.

1 INTRODUCTION

Tunnel construction represents a special discipline in the diverse range of tasks in civil engineering. The interaction between ground, tunneling method and structure requires competence and precision in planning and construction.

The geology and behavior of the subsoil are investigated and recorded at a very early stage of the project by means of extensive explorations and random subsoil sampling. With detailed, precise descriptions of the geology and hydrogeology, subsoil parameters are determined for subsequent planning and construction. Nevertheless, parameter uncertainty cannot be eliminated completely a-priori as a risk factor, as the detailed composition of the subsoil can only be clearly identified during tunnel driving. The risk related to the subsoil composition is often a cost driver and, if inaccurately predicted, presents the contracting parties with major challenges.

Thus, interlocking measurement studies, analyses and planning variants are needed to map and evaluate the uncertainties. The required, extensive analyses can be handled much better with powerful, computational methods. Digitization in the construction industry is therefore of major importance for the handling of complex infrastructure projects.

In the fall of 2021, the “Bundesministerium für Digitales und Verkehr“ therefore published the “Master Plan BIM Bundesfernstraßen (BMVI 2021)”. This follows on from the recommendations of the “Reformkommission Bau” and the step-by-step plan for digital planning and construction and provides a further-reaching implementation strategy for the planning, construction and management of federal highways. The master plan defines the common understanding of BIM as a collaborative, digital working method in federal highway construction. All sides involved in the construction process, such as engineers, planners, contractors, clients and appointed experts, work together on digitally interconnected information models, use extensive project data and share their knowledge with each other. The aim is to make the planning and implementation of construction projects and their subsequent operation more cost-effective, efficient and on-time. (BMVI 2021)

2 REFERENCE PROJECT

The selected reference project in southern Bavaria combines various criteria, including a broad readiness of the project partners, technical features as well as temporal duration of the project. Thus, it was considered suitable to gain initial experience in dealing with digital field applications. The responsible highway board department "Staatliches Bauamt Kempten" planned the bypass of Marktoberdorf and Bertoldshofen and has received technical support in tunneling issues from "Landesbaudirektion Bayern”. The bypass leads through a single-tube road tunnel with a length of about 600 m. Due to the tunnel length, a rescue tunnel branching off perpendicular to the main tube was required in the middle of the tunnel. In addition, an operations building was erected in the north, as well as further technical rooms in the center of the tunnel for the supply and switching of equipment required for construction.

During the construction phase, the tunnel was excavated using conventional shotcrete construction methods. The support ahead of the tunnel face was mainly carried out with spiles and, in a small section, with a pipe shield, due to the low ground cover and adjacent buildings. The tunnel was driven in partial excavation - first the top heading and then the bench and invert - before the interior work with sealing, inner lining and road construction could follow and the subsequent operational tunnel equipment completed construction.

It was not until the start of the tunnel excavation that the client included selected BIM use cases to support project execution, supplementing the conventional method of working. The planning and tendering of the project were still carried out without BIM. The selected focus of action was the tunnel driving and the documentation of the excavation methods, as well as the means of stabilization. In addition to the application-oriented possibilities with BIM, this also marked the successful introduction of digital construction in tunneling.

3 DATAMANAGEMENT AND BIM IN THE CONSTRUCTION PHASE

The special characteristics of tunnel construction, in particular the need for quick decisions based on a transparent database, as well as recurring work processes, create a unique potential for digital handling and the application of the BIM method in construction execution.

In its basic concept, digitization of the construction site offers the prerequisites for better cooperation, more safety and facilitation in the work processes. Ultimately, it should ensure end-to-end transparency for the technical, temporal and financial execution of a construction project and reveal a measure of compliance with required framework conditions. The following figure shows the classic sources of information for a construction site in infrastructure construction as well as their further processing and consolidation in a central data manager in the context of the digital construction site.

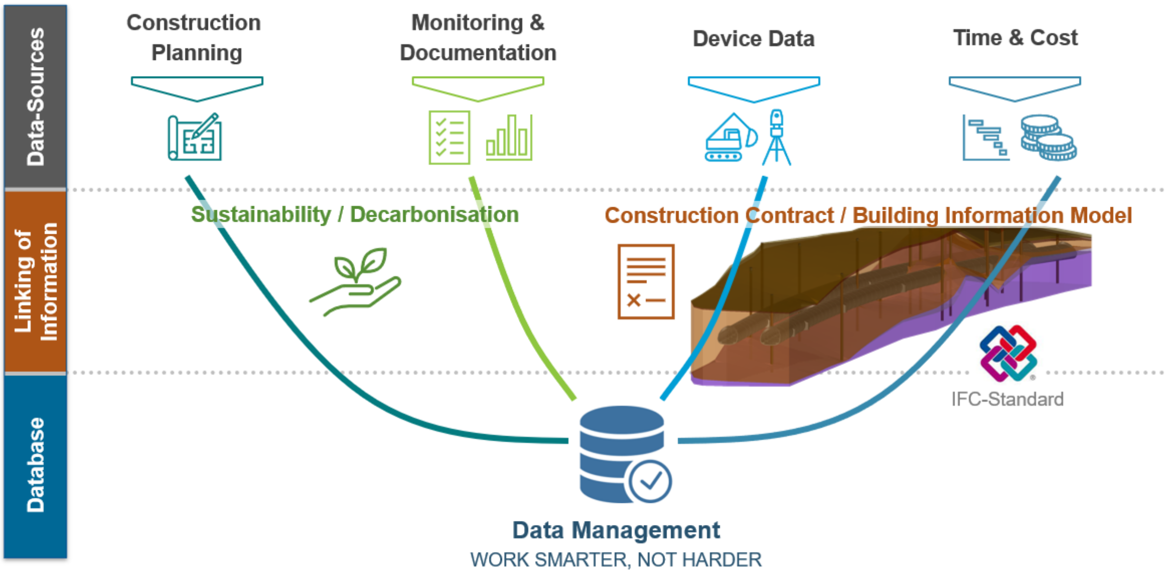

Figure 1. Data management during construction.

3.1 Data-Sources

A large amount of information is recorded every day to control and document a construction site. The idea of capturing important data digitally instead of in paper format and using it more easily via a central information platform in accordance with the "single source of truth" principle (SSOT) is not new and is becoming ever more important with an increase in practical use cases (DAUB 2019). In addition, more advanced approaches, such as the future interaction of Big Data and the BIM method, promise new possibilities for the efficient provision and use of large amounts of data. (Ali & Bandi 2022)

In current construction projects, it can be observed that holistic digital project recording is still rare, although digital information sources are available for machines, equipment and in selected work processes.

In order to create good conditions for further data processing, cloud-based work platforms have proven to be advantageous. Initial experience has shown that information sources and their associated workflows must be aligned extremely precisely with the requirements of project and risk management, so that meaningful and high-quality core data can ultimately be entered into the digital system.

3.2 Linking of Information

The structured input data from the project environment can be flexibly processed and combined in a next step. This process can take place as a pre-implemented process in real time, so that meaningful results are immediately available.

The possibility of directly evaluating compliance with framework conditions, such as sustainability, safety, or general rules and regulations, is becoming increasingly important. The interaction of input data with contract contents, BIM models or other specifications and information has far-reaching potential. In this way, complex issues with multiple influencing variables can be mapped compactly and accurately.

3.3 Database

The consolidation of all project information in a central cloud database has proven to be advantageous for holistic use. For the analysis and visualization of the extensive data, suitable software solutions can be used that allow real-time evaluation through constant synchronization with the database.

For example, the data can be presented in a dashboard by pre-implemented evaluation graphics, clear charts and made available for further decision-making processes. Certain dashboard interfaces within business intelligence software (e.g. Microsoft PowerBI) allow interactive visualizations and analysis functions, so that users can individually display and use data according to their function and responsibility in the project. Particularly in the area of project management, events and circumstances can be better monitored, controlled and communicated.

An efficient data management system creates the following possibilities for all project participants:

- Real-time access to information regardless of location
- Improved quality and transparency of information
- Information and process reliability
- Early conflict detection
- Reliable basis for decision-making
- Meaningful analyses and reliable forecasts
- Targeted management of time and costs
- Evaluation of conditions and specifications to be complied with
- Efficient project and risk management

4 USE CASE IN PROJECT

During the construction of the Bertoldshofen tunnel, the presented approach was used to record the tunnel excavation and the support structures.

The coupling of the input data with the contents of the contract using BIM methods was of particular importance. The following elements, which build on each other, were formulated as targets for tunnel driving and the design of the data system:

- Creation of an As-planned model
- Creation of an As-Built model based on the site information.
- Quantity calculation and control of time and costs
- Target-performance comparison and recording of the causes of changes
- Preparation and analysis of forecast scenarios

In order to be able to adapt to changes in conventional tunneling with regard to excavation and support measures, no rigid BIM model was designed, but a flexible, parameterized environment was created as a modular system. The framework conditions were defined by the contents of the planning and the construction contract. A uniform geometry and attribute definition ensured consistent further processing in all subsequent applications.

Within the system environment created in this way, different states could then be represented as a BIM model by varying the input data:

The excavation model at the time of planning (**As-planned model**) was created based on the predicted excavation and support measures.

The **As-Built model** was successively created on the basis of the site information for the actual constructed state. In order to obtain the information on the selected excavation type and the installed support measures, digital tools for documenting the driving were provided to the construction site and integrated into the system environment as an applicable source of information. A predefined value check during processing made it possible to create an immediate comparison with the framework conditions to be complied with from the contract and regulations. Errors or room for interpretation of any assumptions or interpretations could thus be avoided. The intuitive use, the immediate checking of the data and the predefined workflow ensured broad acceptance among the project participants. With the digital input data, the associated As-Built model could ultimately be successively generated in a short period of time.

The quantitative evaluation of the As-Built model provided the actual billable services at the time of the partial invoice. The direct reference of the data in the As-Built model to the construction site documentation meant that the quantities determined could be traced back to the origin of the information.

In this context, a **forecast model** provided a prediction of the future development of tunneling. For this purpose, various scenarios were designed in order to analyze and display information, such as time of breakthrough, effects of the defined driving methods or monetary considerations in the result. (Hacker & Zeindl 2021)

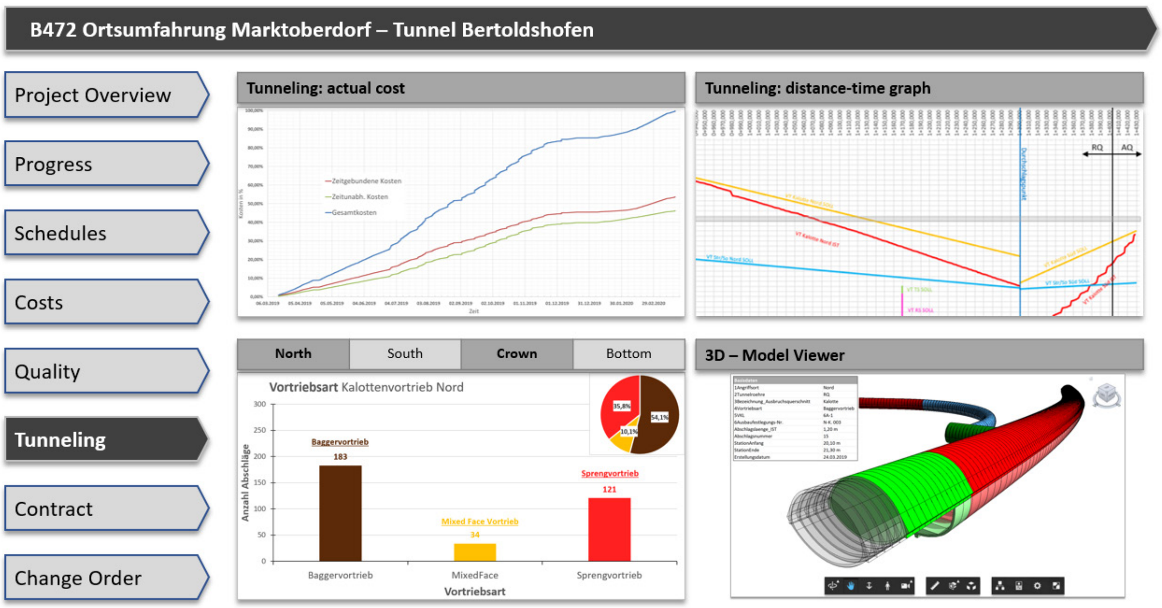

Figure 2. Project Dashboard for tunnelling.

The result and forecast data could ultimately be made available in a central dashboard for those involved in the project. For tunneling, selected graphics and facts were pre-implemented and updated via the input data. The information was an integral part of the construction site documentation and, in particular, supported the project management in making fundamental decisions during the course of the project on the basis of improved knowledge.

5 SUMMARY & OUTLOOK

In addition to the innovative application described in this article, the geology in the tunnel route area was mapped in a spatial model, updated during construction and evaluated by means of quantity calculations and forecasts. In a further, subsequent BIM sub-project of the construction project, the document and defect management for the construction of the structural engineering was then carried out via a digital, model-oriented work platform.

After completion of the construction project, it was concluded that the special challenges in tunnel construction could be successfully mapped with the use of digital processes in combination with

BIM. The advantages lay in the continuous, efficient processing of all decisive parameters and contract-relevant data. The new working methods noticeably supported those involved in the project, and the work to be done was reduced and simplified in several process flows.

The innovative methods proved to be efficient tools in the field of project and quality management, not only for recording time and costs, but also for evaluating results data, as well as explaining the causes of modifications and other technical issues in conventional tunneling.

However, the principle ultimately applies that digital methods or the use of BIM in the project cannot eliminate elementary challenges and uncertainties in tunnel construction. As a high-performance tool, the methods rather support the project participants in information management and the associated workflows. Correct decision-making and appropriate action on the part of the engineers involved continue to be at the forefront of successful project execution.

Ongoing developments in the areas of BIM, process automation, artificial intelligence, and big data indicate that in the future, additional excellent tools will be available to decisively support the planning, construction, and operation of complex and cost-intensive projects.

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