Digitization potential of documentation in tunnel construction

Process evaluation of selected construction sites

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ABSTRACT: As digitization progresses, the switch to computer-aided documentation in tunnel construction is becoming indispensable. Due to inconsistent digital processes, poorly legible handwriting, transmission errors, language barriers and loss of important documents as well as difficult comparability due to subjectivity, there is a risk that information will be incomplete, misinterpreted or lost. As a result, it is difficult to compile and archive the construction documentation without gaps. This costs a lot of time and money. In addition, the quality and sustainability of the building can suffer if documentation for subsequent operation and maintenance is inadequate. This master's thesis evaluates current tunnel construction projects in Europe regarding documentation processes. The aim is to precisely determine the status and to lay the foundations for the development of a software program that links the documentation data directly with a TIM model and thus creates a continuous digital process. To remain competitive, the tunnel construction industry must rethink and find the fastest way to a paperless construction site.

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KEYWORDS: tunnel construction, digitization, documentation, documentation software, documentation process, TIM

1 INTRODUCTION

Documentation creates permanently stored and retrievable knowledge. Essential information about the construction work is valuable for the entire life cycle of the building and should be recorded economically according to the motto 'as much as necessary, as little as possible'. [1] So far, the construction industry has been reluctant to react to the development of digitalization - especially regarding documentation - and is behind other sectors. [2]

2 STATE OF THE ART

The current practice usually is that data is recorded in analogue form and then must be reworked later by site personnel, as it is not available in the desired form from the beginning. [3] With paper-based documentation, it is not possible to compare the TARGET and ACTUAL status at short notice. If data is digitized retrospectively, the construction work has progressed, and the status of the transferred information is outdated. The data should be forwarded to a central system in real time and stored in a structured manner. [4]

Tunnel Information Modeling can be described as a digital, holistic method for structural modeling and focuses on infrastructure and underground construction. The main differences compared to building construction are the uncertainty in the subsoil and the large longitudinal extent of the structure. As infrastructure and underground construction projects are often long, linear, sometimes deep-seated projects, the existing subsoil can hardly be fully predicted despite advance explorations. It is therefore even more important that the model is supplied with up-to-date information during the construction phase to enable direct adjustment measures and realistic, constantly updated schedule and cost estimates. [5]

2.1 Conventional tunnelling

In conventional tunnel construction (ÖNORM B2203-1), at least the three documents are used daily as standard:

- Daily construction reports

- Cycle diagrams

- Cut-off sheets (also called support installation log). [6]

To enable ongoing digital recording, Kvasina et al. have developed a web application in which activities are recorded on a smartphone or tablet, as shown in Figure 2-1. Alternatively, the activity time can be entered via the keyboard or via start/stop buttons with a stored activity cycle. [7]

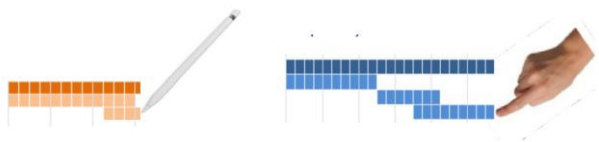

Figure 2-1: Time interval marking on the tablet / smartphone [7]

2.2 Mechanised tunnelling

For mechanised tunnelling (ÖNORM B2203-2), it is recommended that the type and scope of documentation should be defined on a project-specific basis depending on the TBM type. In addition to the cycle diagram and daily construction reports, the following documents are relevant:

- Daily machine reports & data records

- Cutter logs

- Geological-geotechnical records. [8]

3 METHOD

During the master's thesis, three ongoing tunnel construction projects, including one conventionally and two mechanised tunnelling projects, were examined regarding the collection and processing of information. A standardized evaluation form was used to obtain an objective overview of the construction sites. In addition, interviews with the people responsible for the documentation, site managers and foremen, were used to gain practical insights. A guideline-based interview questionnaire was used for this purpose. The interviews were analysed using Mayring's qualitative content analysis.

4 CONSTRUCTION SITE VISIT EVALUATION

All three tunnel construction sites are unique with individually defined documentation. The requirements for the form, type, storage and forwarding of information depend on the type of excavation, the length and diameter of the tube, the deployment of personnel, the geological conditions and the contractual agreements with the client. Conventional tunnelling differs greatly from mechanized tunnelling: less documentation effort, 15- instead of 5-minute intervals in the cycle diagram, photo documentation, a digital signature solution and direct digital software as an in-house development to be independent and be able to realize one's own wishes. Although the TBM generates electronic data through its sensors and the automation is significantly more advanced than in conventional tunnelling, no digital end devices are used. The mechanically driven construction sites both use the machine manufacturer's software and record everything manually in prepared tables. As a result, both construction sites employ at least one person almost full-time to type up the analogue information, running the risk of transmission errors and sometimes keeping documents such as the daily construction report up to four times.

5 INTERVIEW EVALUATION

The interviews confirm the impression of the construction site analysis: the approaches in conventional tunnelling are very good, but there is still plenty of potential. There is a lot of catching up to do in mechanised tunnelling. There is a consensus that the effects of digitalization are largely very positive and that employees use the digital documentation options when they are offered. It is extremely important for everyone that the programs can be operated intuitively via a clear user interface. According to the interview partner, the waste of time and money caused by multiple document management and subsequent transfer to the IT system could be minimized in the future.

6 CONCLUSION

The potential of Tunnel Information Modeling, which involves the localization of information for ongoing documentation and for subsequent operation, is not currently being exploited. The cycle of the central digital twin ends after planning. Only one of the six interview partners talked about the method.

All projects are a long way from a paperless construction site. The analyses of the three tunnel construction sites confirm the study on the digitalization index in Germany presented in the introduction. The digital possibilities that are theoretically already available are largely not yet being exploited. The bureaucratic burden is very high. The necessity of some protocols should be questioned. Table 6-1 shows an excerpt of the documents kept at the construction sites.

Type	What?	Who?	How/Where?	Form?	Further processing?
conventional	Cut-off report	Foreman	Computer in the office	digital	Filing
	Cycle diagram	Foreman	Computer in the office	digital	Daily construction report
	Daily construction report	Foreman	Computer in the office	digital	Construction site management
mechanised	Cycle diagram	Machine operator	Driver's cabine (TBM)	analogue	Digitization construction site management
	Machine data	Machine operator	Driver's cabine (TBM)	analogue	Digitization construction site management
	Cutter's maintenance	Machine operator	On site (TBM)	analogue	Digitization construction site management
	Ring construction protocol	Ring builder & Logistician	On site (TBM)	Scan & analogue	Digitization construction site management
	Daily construction report	Construction site management	Construction site management office	digital	Confirmation client

Table 6-1: Table excerpt of the managed documents

The advantage of using standard software is that it is immediately available and continuously updated. As each construction site has individual documentation requirements, it is difficult for software providers to cover all documents for all projects. It is therefore necessary for the contractual partners to agree on individual requirements and wishes before the start of the project. The disadvantages are the large initial investment and the running costs. With its own software, the company, which implements its own wishes and ideas, remains independent of software providers and can decide for itself in which form which data is recorded and further processed. In the end, the company management must weigh up and decide - depending on the size of the company, the number of tunnel construction sites and the desire for independence, among other things.

7 OUTLOOK

The primary goal must be the development of software programs for the construction companies carrying out the work and their implementation on the construction site. From a holistic perspective, the entire process of a tunnel project should be mapped, from planning to construction and operation - from initial design to maintenance. All documentation data should be available in the cloud system of such a TIM model and enable further use. The investments in digital end devices and software programs should be compared with the personnel hours saved and the non-quantitatively measurable variable of avoiding transmission errors.

As digitization progresses, pen and paper will soon be history. Tunnel construction can experience a revolution with the digital transformation.

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