# Building Information Modeling in Tunnelling – using BIM to develop a 'Temporary Support System' Model for the Underground Opening

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The article describes the practical experience and knowledge acquired during the development of a BIM model representing the temporary support system for the underground opening in a rail tunnel construction project.

**Tunnelling • Underground • Mined tunnelling • BIM • Modelling • Temporary support • LOG • Sustainability • Planning • Construction • Operation • Digitisation**

## 1 Introduction

The phased plan for 'Digital design and construction' as developed by the German Federal Ministry for Digital and Transport stipulates that all infrastructure projects undertaken since 2020 must be executed using the Building Information Modelling (BIM) process [1]. The aim of this guideline is to ensure that projects are planned and executed more efficiently and at the same time that there is greater cost transparency and a higher adherence to delivery dates. The application of BIM is gaining momentum in the tunnel construction sector and clients and contracting authorities, such as the rail operators DB InfraGO AG and the German Committee for Underground Construction (DAUB), have drawn up various requirements and issued recommendations for this particular field of operations [2 to 7].

In the course of the planning phases of a project the BIM model is continuously refined and improved from one stage to the next and enriched with a greater input of details. Here the Level of Detail is defined by the LOG (Level of Geometry) stages 100 to 400. A project study was used to examine the applicability of the LOG stages when modelling the temporary support system for the underground opening for a tunnel project (**Fig. 1**). This involved, firstly, modelling the temporary system for the tunnel in detail in all the LOG stages and, secondly, developing a component library for various supporting elements in the different LOGs.

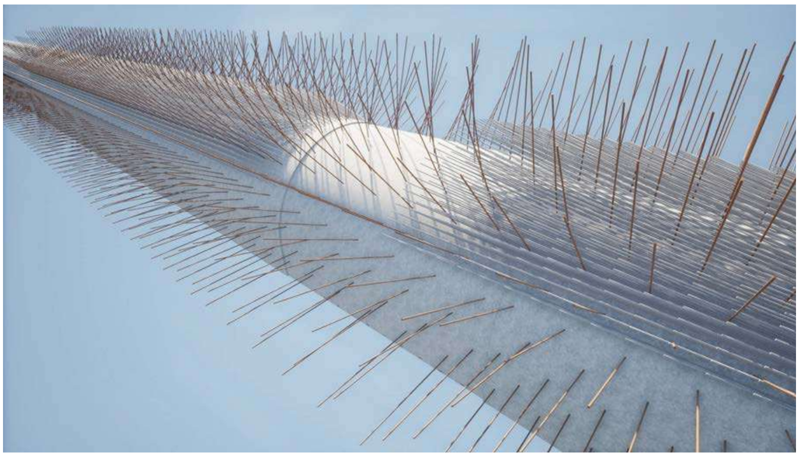

**Fig. 1:** Close-up of the overall 'Temporary Support System' model for drivage classes 4 and 6

## 2 BIM in Tunnelling

The aim of BIM is to improve efficiency in the tunnelling sector. Tunnel construction is one area where it is important to have a very high degree of precision and a carefully considered Level of Coordination between the individual components, together with good technical models. Here BIM can help to provide early identification of potential collisions between components so that these can be averted and rectified at the model planning stage rather than during the execution of the work. In the aggregate, therefore, BIM can help optimise and strengthen the planning, execution and operational processes.

BIM is understood to mean the use of intelligent 3D models for planning, coordination and implementation. Given the size of many of the structures involved in tunnelling projects, however, the requirements imposed by such BIM projects, and hence the type of approach to be taken, are liable to change. As many software solutions are not yet designed to cope with applications at this level new methods have to be explored for the modelling process so that subsequent modifications and adjustments can be made in a time-efficient manner.

## 3 DAUB Recommendations

As far as BIM applications in the tunnel engineering sector are concerned the DAUB is involved with setting standards and laying down guidelines for the standardised processing of tunnel construction projects based on the BIM method. The DAUB therefore makes a significant contribution to the consistent and speedier implementation of BIM in the tunnel construction industry. In this context the Committee has, since 2019, issued various recommendations in six different publications in respect of the requirements relating to the modelling of transport tunnels [2 to 7].

The recommendation [4] also contains, for example, proposals on the degree of detail to be attained by the various tunnel objects in terms of both the LOG and the LOI (Level of Information) that have been used in the project study. The recommendation [4] provides for a breakdown into LOG stages 100 to 400 – with LOG 100 being the least detailed stage and LOG 400 the most. The model becomes ever more detailed as the planning process proceeds. Each LOG stage can therefore be seen as corresponding to a work phase:

- **LOG 100:** preliminary design
- **LOG 200:** design planning
- **LOG 300:** execution planning
- **LOG 400:** tender procedure/execution

Likewise [4] also provides visual examples of proposals for the degree of detail to be met by the tunnel stabilisation elements in the different planning phases.

# 4 Project Study

## 4.1 Support Elements

The project study developed various support elements in line with the recommendations made by the DAUB. The support arch is shown in **Figs. 2 to 4** as an exemplary modelling result. The higher the granularity of the modelled objects, the greater the possibilities for detail application such as the quantity determination of individual objects. An increasing Level of Detail also means that collision checks can deliver a more precise result.

For each ongoing step of the LOG process, with its associated Level of Detail, it is necessary to analyse the added value factor for the intended application. For example, will the connecting elements for the support arch require a very high Level of Detail for subsequent work stages (**Fig. 3**) or will LOG 300 be sufficient for the relevant application? The very same question also applies to LOG 200. Is it necessary to have detailed modelling of a triple-belt system, as a collision test may subsequently be required on a detailed level, for example in connection with systematic roofbolting, or will the much simplified LOG 200 – which involves a clear reduction in workload – prove sufficient for the purpose (**Fig. 4**)?

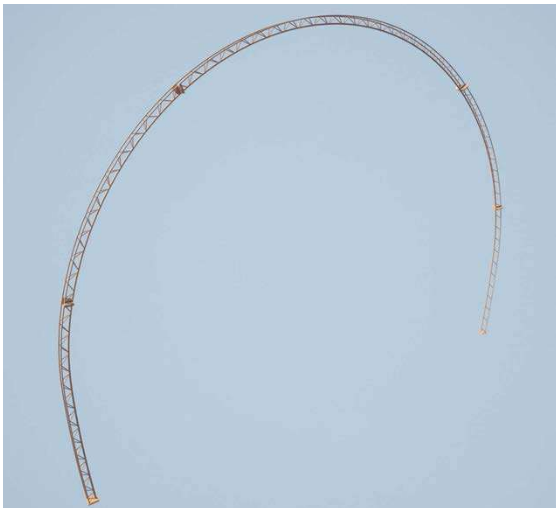

**Fig. 2:** Support arch with LOG 400

## 4.2 Overall Model

The entire modelling process undertaken for the project study on temporary support is based on individual support elements as recommended by the DAUB. These elements were modelled to different Levels of Detail (LOG).

The results of the component model are depicted by way of example in **Fig. 5** and relate to tunnel drivage class 6 and the relevant parameters and support elements. It can be seen that this model contains all the support elements needed for drivage class 6, namely roofbolts, arch supports and spile umbrella screen. If one looks in particular at the Level of Detail of the spile screen and the number of spiles depicted it is apparent that even such a small component model can present many elements to a high degree of detail.

The modelling of an entire tunnel with differing drivage classes will therefore contain a significantly higher number of elements. If a 300 m-long tunnel with the relevant distribution of drivage classes 4, 6 and 7 is to be modelled the appropriate result will be as shown in **Fig. 6**. Because of the high LOG the 300 m-long overall model will contain around 8,500 elements. These details are clearly visible from the different drivage classes and the large number of elements, as particularly evident in

**Fig. 3:** Detail of the support arch with LOG 400

**Fig. 4:** Detail of the support arch with LOG 200

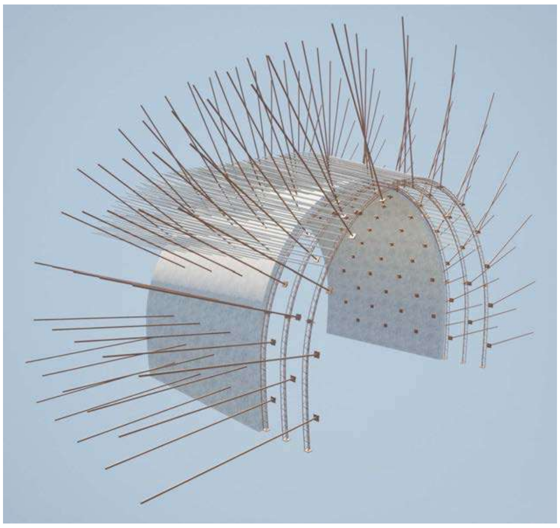

**Fig. 5:** Sub-model 'Temporaray Support System' for drivage class 6

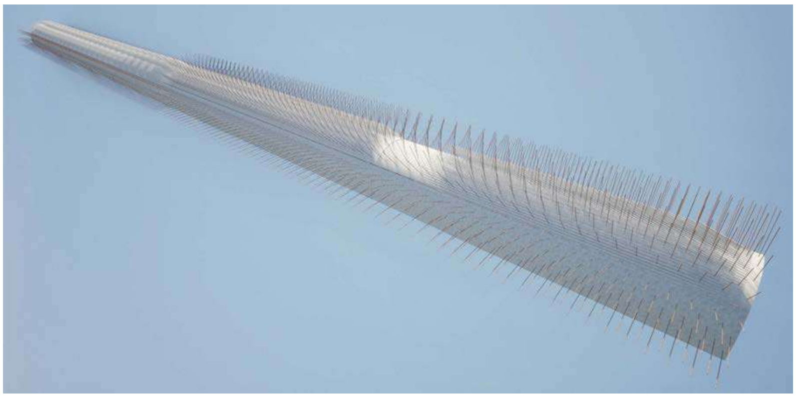

**Fig. 6:** Overall 'Temporary Support System' model with LOG 400

**Fig. 7:** Simplified overall model

the close-up view shown in **Fig. 1**. However, in the same context this means that the PC has to have a high computing capacity and that the Level of Detail required for the whole model will result in large volumes of data, a fact that will greatly restrict performance when it comes to using the model. Given that many transport tunnels are much longer than 300 m it will quickly become apparent that developing an entire model in this way could prove very difficult. In view of this fact it is generally advisable to use a simplified overall model where the individual application permits.

## 4.3 Simplified Overall Model

The DAUB recommendations propose working with a simplified overall model which only recreates the drivage classes over the course of the tunnel. In this case each drivage class has a different colour for the visual representation of individual drivage-class zones. All necessary detail information is therefore presented using comprehensive attributes. The simplified model used for the project study is shown in **Fig. 7**. Here, handling the technical model becomes a much simpler procedure. However, one of the drawbacks of the simplified overall model is that it is not possible to carry out collision tests, for example between the tunnel roof-bolts or pipe screen and adjacent objects and structures, as the support elements with their spatial reach are not present.

## 5 Conclusion

Overall, the project study shows that the BIM method, when used in the tunnel construction sector, offers huge potential for more sustainable planning, construction and operating processes. By supporting the construction principle of 'first digital, then for real' [1] it is able to contribute to the common goal of the various stakeholders involved in the Future Initiative Railway Construction (ZIB) [8]. Application scenarios, such as quantity determination and collision testing, can be effectively implemented as a function of the different LOG stages.

What has become all too apparent, however, is that such a high Level of Detail generates huge volumes of data and therefore expends an enormous computing capacity, with the result that it cannot usefully be applied in performance terms over an entire tunnel of several kilometres in length. On the other hand, the simplified model does offer a good solution here, and while not replicating the different elements in their geometric form it does nevertheless embody all the other features in the form of attributes. The simplified overall model can, if necessary, be expanded to provide a high Level of Detail in specific sub-sectors, which means that particular applications can be individually targeted.

## 6 References

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