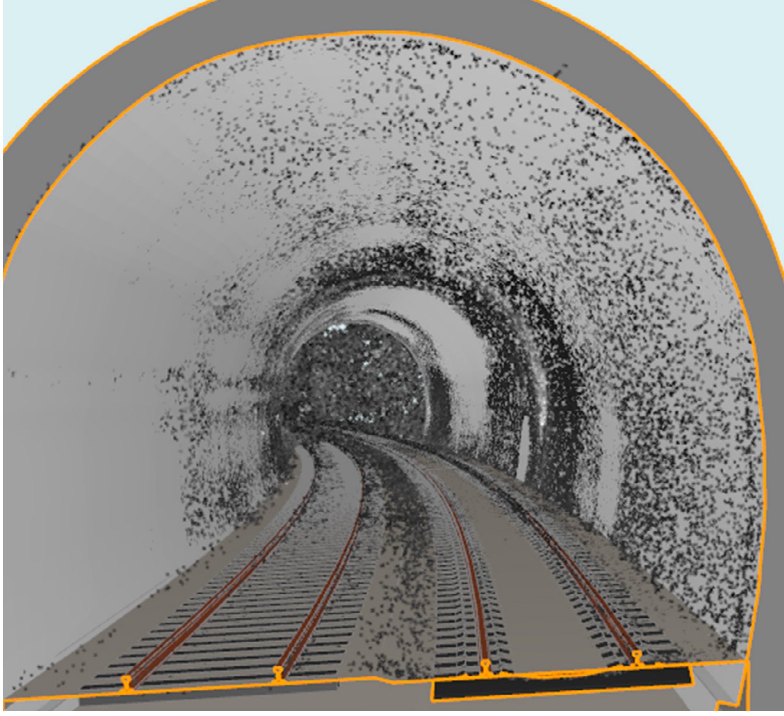
ALLPLAN in practice | Infrastructure construction

AS-BUILT MODELING IN TUNNEL CONSTRUCTION: UNIQUE CHALLENGES

As-built modeling is one of many planning challenges involved in renewing a rail network. Two current tunnel construction projects illustrate a typical BIM application.

Apart from muscle-powered vehicles like bicycles, rail is clearly the most sustainable means of transport we have. However, a large part of Germany's rail infrastructure is well over 100 years old. Even the most recent repairs were carried out decades ago in some cases.

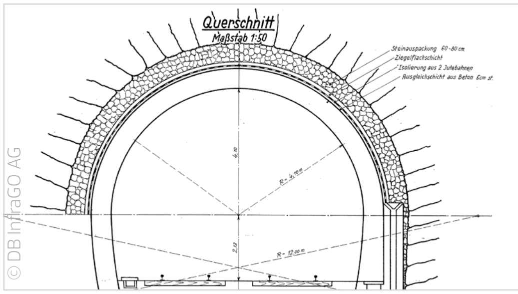
Against this backdrop, it is clear that numerous sections and structures of the 30,000 km network are in need of renewal. However, construction work on existing rail infrastructure regularly presents considerable planning challenges – one of which is the as-built modeling of existing tunnel structures. The main issue is that the information that can be gathered from the interior surface within the mountain differs greatly from the data available within the tunnel. Two current tunnel construction projects – including the renovation of the Schellenstein Tunnel near Olsberg and the Gudenhagen Tunnel near Brilon – highlight this challenge. In both cases, KREBS+KIEFER has been commissioned by DB InfraGO AG as general planner and is responsible for overall BIM coordination.



The interior of the tunnels can be captured with high precision using laser scanning. The point cloud generated in this process comprises around 800 million points. On the mountain side of the tunnel, this is offset by only two dozen exploratory boreholes.

Two typical tunnels

Both structures are examples of numerous engineering structures on the German rail network.



The Schellenstein Tunnel, built in 1870/71, is located on the double-track line 2550 between Aachen Central Station and Kassel Central Station and passes under the „Im Hagen“ hill (485.5 m above sea level) over a length of 247 meters. The tunnel and its portals were renovated in 1988/89. The 280-meter-long, single-track Gudenhagen Tunnel, built in 1901, is part of line 2961 between Paderborn Central Station and Brilon Wald. It passes under the foothills of the Hängeberg ridge (547 m above sea level).

Both tunnel structures were built using mining techniques and have a horseshoe profile. Their poor structural condition makes renovation necessary. Planning for both projects began in December 2023.

PROJECT INFORMATION AT A GLANCE

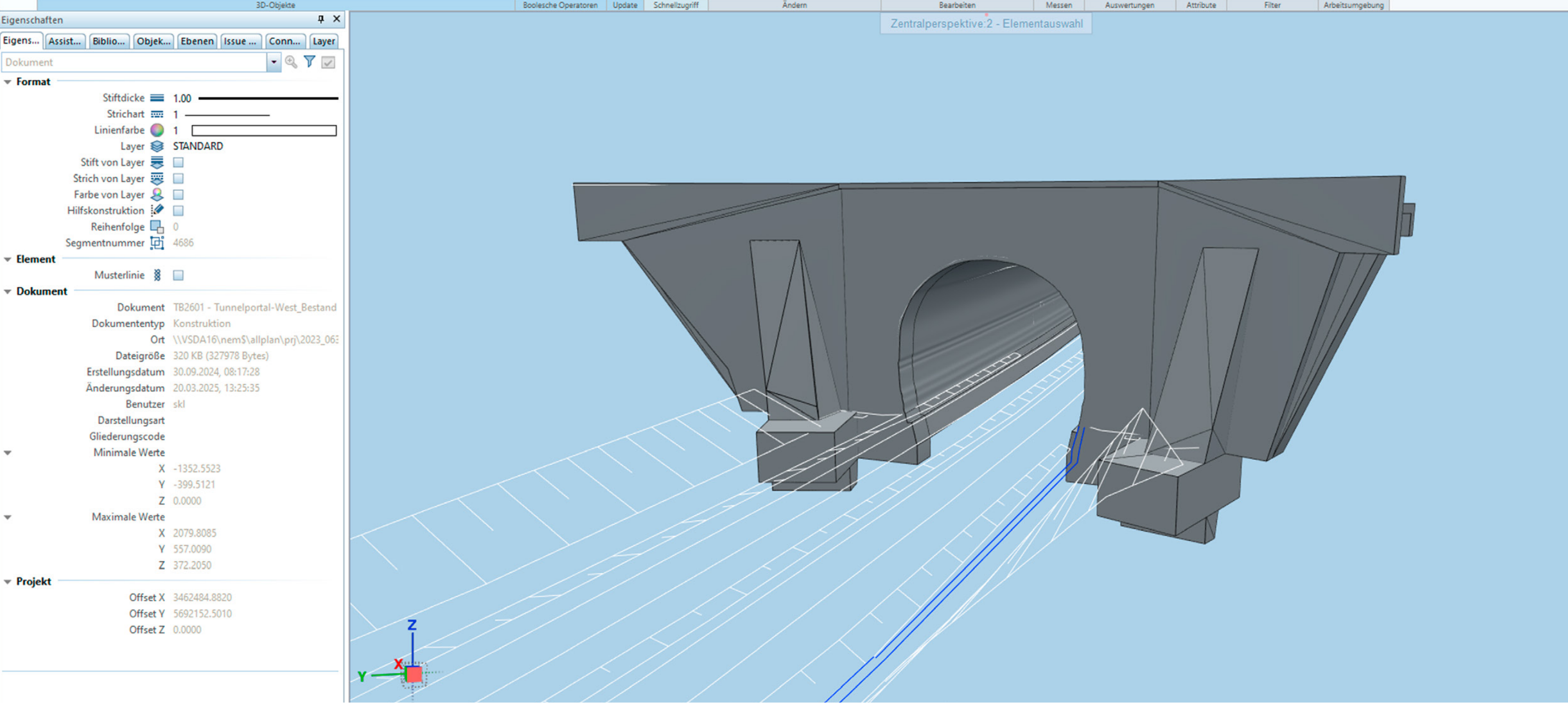
- **Focus:** Infrastructure construction
- **Software used:** ALLPLAN, Scalypso, CloudCompare

Project

- **Client:** DB InfraGO AG
- **General planning:** KREBS+KIEFER Ingenieure GmbH
- **Project start:** 12/2023

As-built modeling: 800 million points vs. 25 boreholes

As with many public infrastructure projects, BIM is also being used for the planning of the two tunnel renovations. One of the earliest steps is the as-built modeling. As is typical for such old structures, only a handful of documents from the construction period or from minor repair work are available. Due to their age, these are hand-drawn drawings that have since been scanned. The existing planning material therefore provides little information about the actual condition of the structures. The focus of the as-built modeling is therefore on capturing the current state of the two tunnel structures using 3D surveying and additional exploratory measures.



In as-built tunnel modeling, the combined borehole and point cloud cross-sections were extruded from cross-section to cross-section. The foundations of the portal wall were modeled using drawings from the year of construction.

On the interior of the tunnel, a 3D laser scanner is used, which is driven through the respective tunnel. The point cloud generated in this way only captures the visible interior of the structure as well as the tunnel portals and cut slopes. With approximately 800 million points and a data size of 14 GB, the data available at this point is extremely accurate. Within the mountain side of the tunnel, however, there is only a site investigation with 25 boreholes, from which five exploratory cross-sections of the tunnel wall, each with five exploratory boreholes, were produced. This is an enormous discrepancy, which plays a major role in application-oriented as-built modeling.

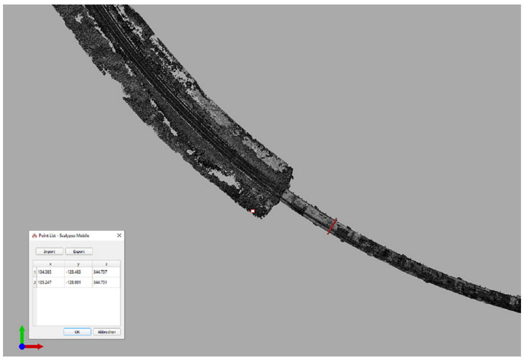
The creation of as-built models should always serve the project objective. Therefore, it is not expedient to actually process the many millions of points on the tunnel interior while only mapping the rock side with just 25 points. The resulting volume model of the existing tunnel interior would require an interpolated interpretation of the rock side of the inner tunnel shell. However, the actual course of the rear edge of the inner shell between the exploratory cross-sections is unknown. In this case, the apparent accuracy on the rock side of the inner shell would therefore only be illusory.

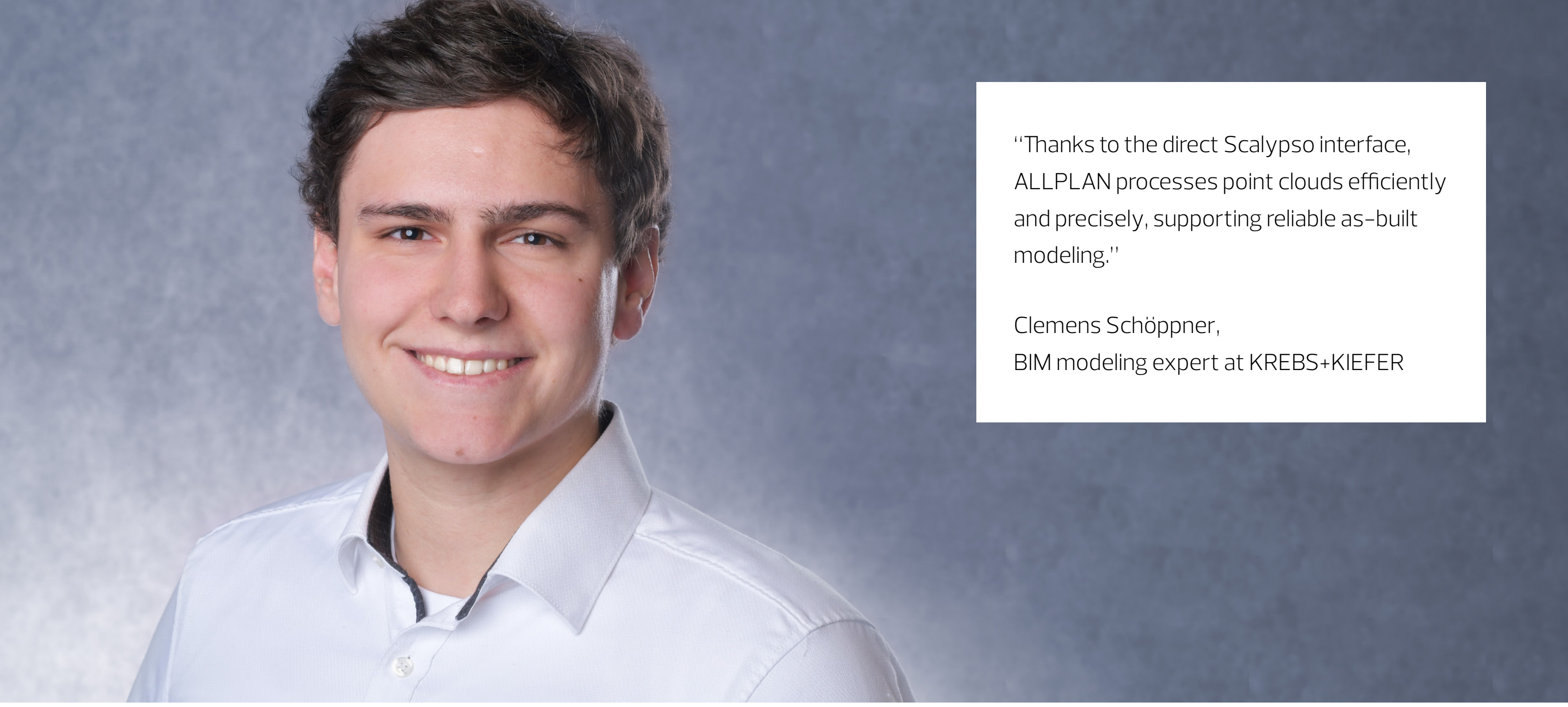
For this reason, KREBS+KIEFER opted for a simplification when creating the as-built models. Sections from the area of the exploratory cross-sections are extracted from the 3D laser scan. These serve as the data basis for each of the five areas, spanning halfway to the next exploratory cross-section. Although this results in a deviation from the actual laser scan over the entire length of the tunnel, the data density on the inside reflects a comparable level of information to that on the mountain side.

Modeling workflow with ALLPLAN and Scalypso

In order to create an as-built model that was appropriate for the project objective, the first step was to determine the position of the borehole cross-sections along the route axis. At these points, KREBS+KIEFER transferred the corresponding cross-sections from the point cloud via live transmission from Scalypso mobile to ALLPLAN.

To do this, the enormous size of the survey data had to be handled in advance, which is why the point cloud was loaded in compressed form into Scalypso to define the transfer cross-sections. Thanks to the direct interface to ALLPLAN, these could then be transferred quickly and easily to the modeling software.

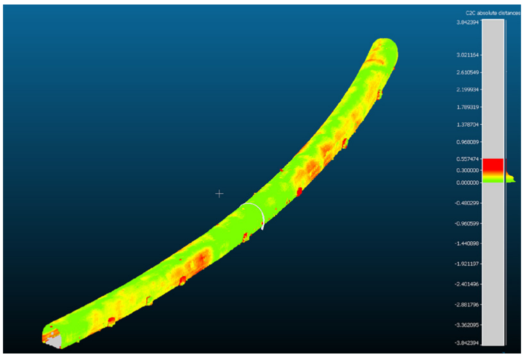




"Thanks to the direct Scalypso interface, ALLPLAN processes point clouds efficiently and precisely, supporting reliable as-built modeling."

Clemens Schöppner,
BIM modeling expert at KREBS+KIEFER

For better processing, the working plane in ALLPLAN was defined for the cross-section to be processed (positioned parallel to the position of the cross-sections). The actual tunnel cross-section could now be generated from the combination of the borehole cross-section (tunnel wall thickness) and the point cloud cross-section (tunnel interior). Since the foundations of the tunnel inner shell could neither be explored in detail nor recorded by laser scan, they were modeled using drawings from the year of construction. To generate a 3D object from the created 2D cross-sections, these were extruded along the tunnel axis from exploration cross-section to exploration cross-section, with two cross-sections always „coming towards each other" and meeting in the middle between two exploration cross-sections. The tunnel portals were modeled based on the as-built plans and survey data. For quality assurance purposes, the as-built model was compared once again using CloudCompare with a surface model generated from the point cloud. Color coding provides information about any deviations.



Further BIM use cases with ALLPLAN

KREBS+KIEFER will continue to rely on ALLPLAN as the project progresses. Among other things, the software will be used to model the variants for the replacement tunnels. For creating visualizations, engineers also benefit from another practical interface in ALLPLAN: the Twinmotion Direct Link not only allows models to be easily transferred to the visualization software, but changes in the modeling are also synchronized in real time in Twinmotion. In addition to high-resolution renderings, the program also enables VR tours of the models created.

The ALLPLAN team provided advice and support for this project with its expertise in digital building modeling.

"The combination of ALLPLAN and Scalypso makes it possible to implement BIM use case 020 – building information modeling – for complex structures such as tunnels in a very cost-effective manner."

Michael Sklorz,
Authorized Signatory, KREBS+KIEFER

The customer

KREBS+KIEFER provides engineering services for the most demanding construction projects. Its range of services goes far beyond the usual engineering services and covers the entire life cycle of a building – from the initial idea to planning and implementation to maintenance. More than 800 employees at 17 locations contribute their specialist and practical expertise, with personal support to achieve the best solutions for customers and partners. In line with its mission statement, „GIVING THE FUTURE SPACE," the company, founded in 1950, focuses on innovation, diversity, and competence as qualifications.

About ALLPLAN

ALLPLAN is a global provider of AEC software with BIM solutions for architecture, structural engineering, detailing, fabrication and construction. True to our "design to build" claim, we provide tools that enable earlier data-driven design decisions, support digital fabrication and leverage information throughout the entire construction process. Integrated cloud technology further optimizes interdisciplinary collaboration on building and infrastructure projects. Our innovative workflows empower architects, engineers, and construction professionals to deliver their projects more productively, safely, and eco-consciously.
Around the world, over 700 dedicated employees continue to write the ALLPLAN success story. Headquartered in Munich, Germany, ALLPLAN is part of the Nemetschek Group – a pioneer for digital transformation in the construction sector.

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Cover image: Numerous engineering structures on the German rail network are outdated and in need of renovation. Modeling the existing structures is one of the particular challenges in planning the renovation projects.