Digitalised planning, construction and infrastructure management

Digital track planning has evolved significantly since its first use. By refining systems for recording the inventory, the achievement of surveying accuracy and the addition of further modern sensor technology, data is now being generated that can be used in a variety of ways even after planning and deliver sustainable value for infrastructure operators.

Marc Kückmann
Head of the Karlsruhe office
Obermeyer Infrastruktur GmbH & Co KG
marc.kueckmann@obermeyer-group.com

Maximilian Bade
Head of the Digital Planning department
Obermeyer Infrastruktur GmbH & Co KG
maximilian.bade@obermeyer-group.com

Steffen Scharun
Head of BIM
Obermeyer Infrastruktur GmbH & Co KG
steffen.scharun@obermeyer-group.com

1. Introduction

Up to now, it has been common practice and prescribed by the DB regulations to carry out site inspections of the project area in rail infrastructure projects in Germany in order to improve the often insufficient inventory data and to create a secure basis for planning [1]. This requires employees of the client and the planning office to move around in the immediate hazard area of railway tracks and use manual methods (measuring wheel, tape measure, clipboard, camera) to determine the inventory situation and provide analogue documentation. For long track construction projects on busy routes in particular, this takes long periods of time and causes a safety hazard to those involved, and greatly restricts railway operations on these sections. The largely analogue results of such inspections no longer suit the status quo of the era of digitalization, so they require painstaking rework that is susceptible to errors.

Digital alternatives to time-consuming inspections and data preparation have therefore been sought – and found in the form of kinematic recording systems and the consistent use of the data thus collected in planning and execution processes. These recording systems move at speeds of up to 100 km/h on tracks through the entire project area, using various sensors to collect data on the current inventory situation in a digital form.

This avoids endangering employees, greatly enhances the speed and accuracy of inventory recording, and enables its consistent further processing.

The uniform use, preparation, and delivery of such data allows it to be used throughout the system's life cycle, greatly reducing opportunities for information loss at the interfaces currently common.

2. Beginnings of digital track planning

In preparation for the initial projects, the Obermeyer engineering office produced a master's thesis that extensively compares the systems currently on the market. The clear conclusion was that at that time no complete system was ideally suited to railway technology. Instead, it recommended using an individual system made up of high-precision scanners and a multi-camera system designed for use on roads [2]. The first use of such a system involved a high degree of pioneering spirit and close cooperation between client, contractor, and the service providers involved. The first system consisted of two transporters with the necessary measuring and sensor technology loaded onto a flat wagon.

More application-specific sensor technology was mounted directly on and under the flat wagon, entailing a considerable amount of preparation and calibration effort.

From the beginning, the focus of development was on a holistic consideration of inventory by means of a combination of sensors including laser scanners, cameras, and georadar sensors to digitally record the track body in its entirety.

At the same time, preparation for consistent use of the data collected and a continuous digital workflow was begun and the refinement of the Obermeyer's design software, ProVI, pushed forward so that the results could be processed for planning. Automatically identifying the actual position of the tracks in the data collected was a challenge that was successfully solved. From this point, the solution allowed laser scan data to be linked to read-in route information and the two processed together.

Implementation in the software allowed axle-based inventory modeling in a data model while the data were referenced to the stationing axles for the routes detected.

3. Refinement and consistent workflow

The very first applications of this new approach showed that digital inventory recording delivered greater precision and more reliable information than the previously-used inventory documentation, enhancing planning quality and efficiency.

It was also clear that the system's measuring accuracy must be enhanced if true digital track planning was to be implemented in a consistent, continuous data workflow.

This insight also showed the developers that more sensors were needed, since initial pilot attempts at achieving the measuring accuracy from the laser scans taken at high travel speeds were only moderately successful.

At the same time, Plasser & Theurer introduced the concept of the EM100VT, based on the EM-SAT at the VDEI conference on railway construction in Darmstadt. The concept included a measuring system for detecting the relative track position while moving at up to 100 km/h. The vehicle's technical equipment thus offered the capability of significant refinement of kinematic inventory detection. So Obermeyer and Plasser & Theurer decided to refine the concept in close cooperation. This cooperation was first introduced to the public as "digital track planning" as part of InnoTrans 2018, giving rise to the joint idea of a holistic, highly precise inventory recording that combines track position detection with a fixed-point measuring system (tmRTG) and a mobile mapping system (Riegl VMX-Rail).

This approach differs considerably from other systems, which record inventory with GNSS, whose accuracy is limited and which is difficult to control because of outside influences. This means that these systems can be used for only parts of railway infrastructure recording such as providing the basis for ETCS equipment as part of Digitale Schiene Deutschland. The accuracy available with GNSS systems is not sufficient for track construction projects. The data would thus not be further usable in such projects.

To ensure that data collected had unlimited use, the fixed-point measurement system was systematically refined in collaboration with Plasser & Theurer and Track Machines Connected (TMC). At the end of this development, track measurement product approval according to Ril 883 was applied for and obtained, making it the first system on the market with such approval. To achieve this, a reference route was kinematically measured and the results scientifically compared with those of a simultaneously performed tachymetric measurement.

The measurement data generated, linked with the environment data from the mobile mapping system, forms the basis of a consistent digital workflow and thus for actual digital track planning [2].

1: EM100VT in productive operation in Germany

4. Use of digital route planning

From the development steps to an actual digital track planning system, there are several different use cases. The three already implemented in the German market will be described below using specific project examples.

4.1. Inventory recording as the basis for planning railway renovations

Development originated with the project for renewal of the high-speed railway line between Mannheim and Stuttgart (SFS 4080) in 2020. After the contract was granted in 2016, a comprehensive market analysis was performed, resulting in the implementation of the individual solution described above. It was the first time that the measurements were consistently digitally processed with a data model from the kinematic recording procedure. This included virtual inspections in the laser scan and extensive image documentation as well as planning of subsoil improvements based on georadar images. It saved 60 inspection days and allowed necessary planning documents such as obstacle lists to be generated from the data model.

The data were combined with relative accuracy with the known railway axes. A pilot 3D model of a short track section was also generated (Figure 2) [3]. Afterwards a comparable system was used for the renovation project on the Schwarzwaldbahn between Hornberg and St. Georgen. In addition to the proven combination of laser scanning, photo documentation and georadar, kinematic measurement was also tested at 30 km/h. Fixed point signage (30x30 cm) was set up on the track, calibrated tachymetrically, and detected in the laser scan data with an algorithm.

Despite problems with inconsistent coordinate systems for the existing infrastructure data, presentable successes were achieved.

The procedure could not be used for the next large-scale project, the renovation of the SFS 1733 between Kassel and Würzburg, for safety reasons. No large fixed-point panels could be set up, especially in tunnels. So only the established workflow of kinematic inventory recording and complete digital planning of inventory renewal was performed in the digital data model. However, this was the first project in Germany to use the EM100VT. The project was also a turning point in development, since it involved the first piloting of the fixed-point measuring system developed by Plasser & Theurer to be used on a short test track in Germany.

4.2. Kinematic measurement

System approval for track measurement according to Ril 883 was an important prerequisite for wider dissemination. The creation of a secured, georeferenced, highly accurate basis for planning, especially for busy tracks, is currently a primary use case.

On busy routes with high train frequency, track measurement is now accompanied by high-precision kinematic inventory recording. The inventory is thus measured according to valid guidelines without operational restrictions or personnel in the hazard area and recorded completely and digitally with the additional sensors on the measuring vehicle.

The system has already been used productively more than once. On the busy

2: SFS 4080 as-built model

3: Colored point cloud from the Offenburger Tunnel project

Fürth – Würzburg corridor, 154 km of track were successfully measured kinematically on a single day. During preparations to renew the highly-trafficed Riedbahn corridor, the busy line between Frankfurt and Mannheim was measured in a weekend effort and the results used as a basis for further planning activities.

4.3. Kinematic recording as a basis for BIM inventory modelling

Another important use case is kinematic recording as a basis for BIM (Building Information Modeling) inventory modelling. BIM projects require inventory model generation in order to integrate the planned infrastructure into the existing inventory. Conventional methods soon reach their limits, especially in areas where there is extensive intervention in existing railway infrastructure.

Colored, highly accurate point clouds and extensive photos can be used to achieve very high precision in BIM inventory modelling and its visualization. This approach was first used as part of the Karlsruhe – Basel large-scale project in Planning Permission Section 7.1, planning of the Offenburg Tunnel (Image 3) [4].

5. Refinement outlook

As the concept was gradually refined, it became clear that such a system has enormous potential for condition monitoring as well as assisting the system operator in system and maintenance management. For this to work, sensors are added to the original system to achieve an even more comprehensive image of the existing assets. It is also necessary for the kinematic measuring system to move regularly through the system network to detect changes.

This could be done during regular operations and would enable the system operator to manage system inventory more intelligently and efficiently. It would also gradually improve the store of inventory data, which is currently insufficient. In the future the great effort needed to generate and process this data at the beginning of a project could be eliminated, since the data could be called up directly from an inventory system.

Refinement will continue to focus on simplifying and automating post-processing of recorded data. This requires processing the large quantities of data intelligently using AI methods and gradually reducing manual effort. Approaches have been developed as part of the RailTwin research project by the Technical University of Munich, Obermeyer, and ProVI and successfully tested based on data collected as part of digital track planning.

Ideally, the data collected will be combined with BIM data from various infrastructure projects. In this way, the owners receive as-built documentation forming the basis for an asset model of their inventory. The existing BIM models from planning and construction execution can also simplify processing of the data collected by the kinematic measuring system, as they can be better classified and assigned to asset structures.

6. Summary

Kinematic recording with a multi-sensor vehicle forms the basis of a highly accurate digital inventory model.

Tracks can be planned digitally and in compliance with BIM based on this inventory model. Building on this, modelled planning in an overall model forms the basis for construction. And after the project has been implemented, this basis can be used for continued infrastructure data management.

However, it is only when the kinematic inventory detection is linked with guideline-compliant track measurement that digital track planning will deliver a highly accurate, holistic inventory model that meets all infrastructure operator requirements, and is therefore universally applicable.

Literature

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