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Hakan joined Bentley Systems in 2005 and is a Senior Product Manager, Civil Engineering.

Hakan previously served as a Senior Consultant. Before joining Bentley, Hakan worked at the Head office of the Swedish National Rail Administration, an EPC company and at an IT consultant company. Throughout his career, Hakan has focused on Railway designs, with a particular interest in high-/low voltage electrical and Signalling. He holds a degree in Mechanical/Electrical Engineering.

Dan has spent his career helping advance the engineering practice through technology and innovation using Bentley's civil design software.

He works with departments of transportation and engineering firms around the world to discover areas of need, guides development of Bentley's Road and Rail design software, and educates software users to leverage technological advancements to become more efficient and produce advanced project models that have value beyond a set of construction documents.

EFFICIENT RAILWAY INFRASTRUCTURE THROUGH DIGITAL INNOVATION

KNOWLEDGE 200
DIGITAL & AI

Throughout history, the rail sector has played an important role in the advancements of technology and civilization. The earliest railroads shrunk the world as it became possible to move people and goods across great distances at previously unheard-of speed and accessibility. Railways were at the forefront of new technology throughout the steam, diesel, and electrical eras. They were at the core of engineering advancement and growth of society through bridges, tunnels, metros, and even standardized time zones.

Today, railroads continue to be part of important advancements in engineering, technology, and society. New projects like the east-west Elizabeth Line through London and future north-south HS2 corridor certainly provide substantial increased mobility and efficiency for their riders. But these projects also usher in the need for significant advancements in how modern-day railroads are designed, constructed, and maintained. In 2018, Bentley Systems introduced OpenRail Designer to replace its existing Bentley Rail Track design software. OpenRail Designer enables detailed engineering and 3D design of track that supports digital workflows, where engineering deliverables are meant to be reused throughout the asset lifecycle, playing a vital role in delivering safe and reliable operations.

Safety is a key responsibility of rail infrastructure owners and operators. In the United Kingdom alone, there are 20,000 miles of track, 30,000 bridges, tunnels, and viaducts, and thousands of signals, level crossings, and stations that must be thoroughly inspected, repaired and maintained. With infrastructure under constant stress from weather and increased capacity demands, the scale of the challenge facing the industry is clear. Railway owners and operators must balance public and employee safety obligations with economic pressure to maximize efficiency and minimize costs related to maintenance.

When working on new or legacy rail systems planned for expansion or modernization, early adoption of intelligent modeling and digital delivery is essential to lay the foundation for successful rail operations and maintenance.

The traditional design process is labour intensive, requiring multiple draftspersons to do manual CAD work to create drawings. That process makes change management difficult, with any change to the track design requiring significant rework of the drawings. These 2D-centric workflows also lack 3D modeling for design checks, clash detection, and BIM requirements. Automation is limited, and is often driven by spreadsheets and custom macros, which are prone to human error.

Adopting OpenRail Designer's intelligent 3D modeling and a connected data environment to improve workflows, optimize project delivery, and improve overall service, safety, and reliability is a first step to preventing failures and unplanned downtime.

BETTER UNDERSTAND EXISTING CONDITIONS

Regular inspections and preventative repairs are a fundamental component of railway maintenance. Today, manual track inspections

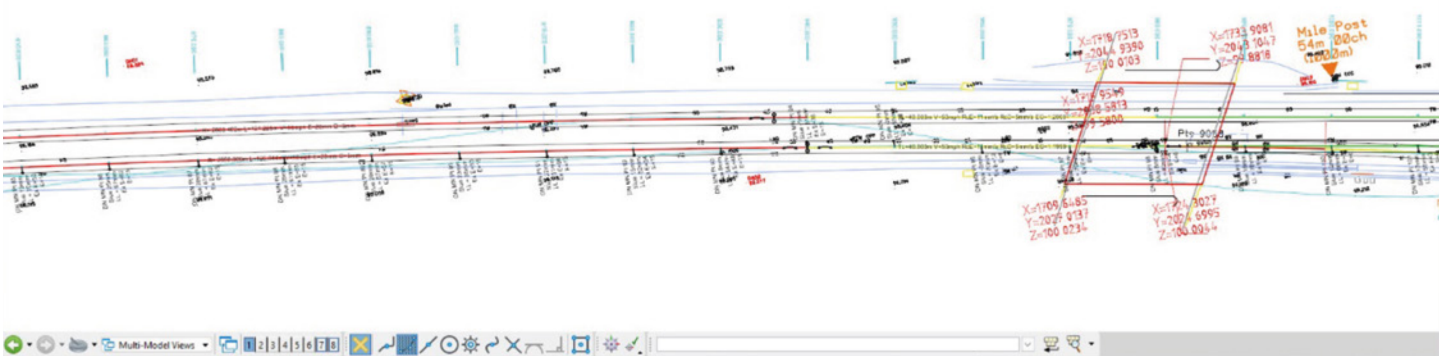

Figure 1: Understanding existing conditions.

by rail professionals are still a common form of data acquisition. Technology plays an important role in facilitating and supporting experienced personnel to increase the frequency and accuracy of track monitoring activities, helping them to better understand existing conditions. Combining technology with industry knowledge and experience enables engineers to prioritize critical maintenance. Leveraging drones and Internet of Things (IoT) sensors can enable large sections of the railway to be surveyed quickly and cost effectively. AI and machine learning can support the analysis of large volumes of track imagery and data to identify maintenance needs, proactively addressing potential issues.

Periodically surveying the rail positions provides inputs for calculating rail parameters, such as rail gauge, Cant, and curve radii used to analyse the condition of the railway geometry. The amount of survey data generated is massive and virtually impossible to manually analyse. The ability to compare and analyse multiple surveys conducted over time improves decision-making.

For example, consider a survey, such as in **Figure 1**, showing the elevation of one of the rails is decreasing resulting in an unwanted twist of the rails. This condition not only decreases passenger ride comfort but could potentially develop into an unsafe situation. Comparing surveys done over time can provide crucial information for understanding the development of the issue and predicting how quickly it might progress. If the decrease of the rail elevation has not changed in recent surveys and the elevation difference is within tolerance, this issue will need to be monitored in future surveys but may not require immediate maintenance. However, if the rail elevation difference is increasing in recent surveys, maintenance may be needed. Periodically surveying the same railway and comparing the survey data provides information to predict when a fault will reach its threshold value, and the situation may become unsafe. Using modern technology, such IoT, to monitor rail conditions in real time can expedite the analysis and prediction of required railway maintenance.

USE DATA TO INFORM DESIGN

The survey data normally consists of 3D points—horizontal location and an elevation—along the inside of the railhead, or it could include calculated points from the rails forming the centreline of railway.

There are many ways to collect data points, such as extracting the points from point clouds and photogrammetry, specialized track surveying equipment, or IoT track sensors. No matter how the data is collected, it is important to understand the age of the survey, the accuracy of the data, and the coordinate system in which the points are aligned.

REGRESSION DESIGN, AN ITERATIVE APPROACH FOR BETTER OUTCOMES

OpenRail Designer provides the common data environment to view, analyse, and compare current survey data with historic models from previous maintenance or renewal surveys.

When an area requiring work is identified, the railway geometry is modeled describing the corrections that need to be made to the railway. This work is called regression design.

The survey data is handed over to a track designer, who regresses or re-creates a suitable railway centreline geometry that fits through the survey points. It is not possible to create the geometry exactly matching the survey data, since the survey is the current position of the railway, which has moved from its desired or optimal position. The track designer will regress the railway both horizontally and vertically while also taking into consideration the Cant, which is directly related to the route speed, rail gauge, and curvature. The track designer's knowledge and experience are crucial in the iterative regression design process to create a desirable track geometry with suitable Cant and provide minimal physical impact to the neighbouring tracks, equipment, and infrastructure. Both graphical and tabular feedback as shown in **Figure 2** aid the track designer when regressing the geometry. The model-based environment of OpenRail Designer provides both the engineering toolsets for track alignment regression and the 3D models for efficient design review and clash detection.

Before construction begins, a new track survey may be collected and the initial regression design compared against the new survey to validate that the proposed solution is within the appropriate design standards. Any design adjustments and revalidation are easily performed at this stage before the final approval.

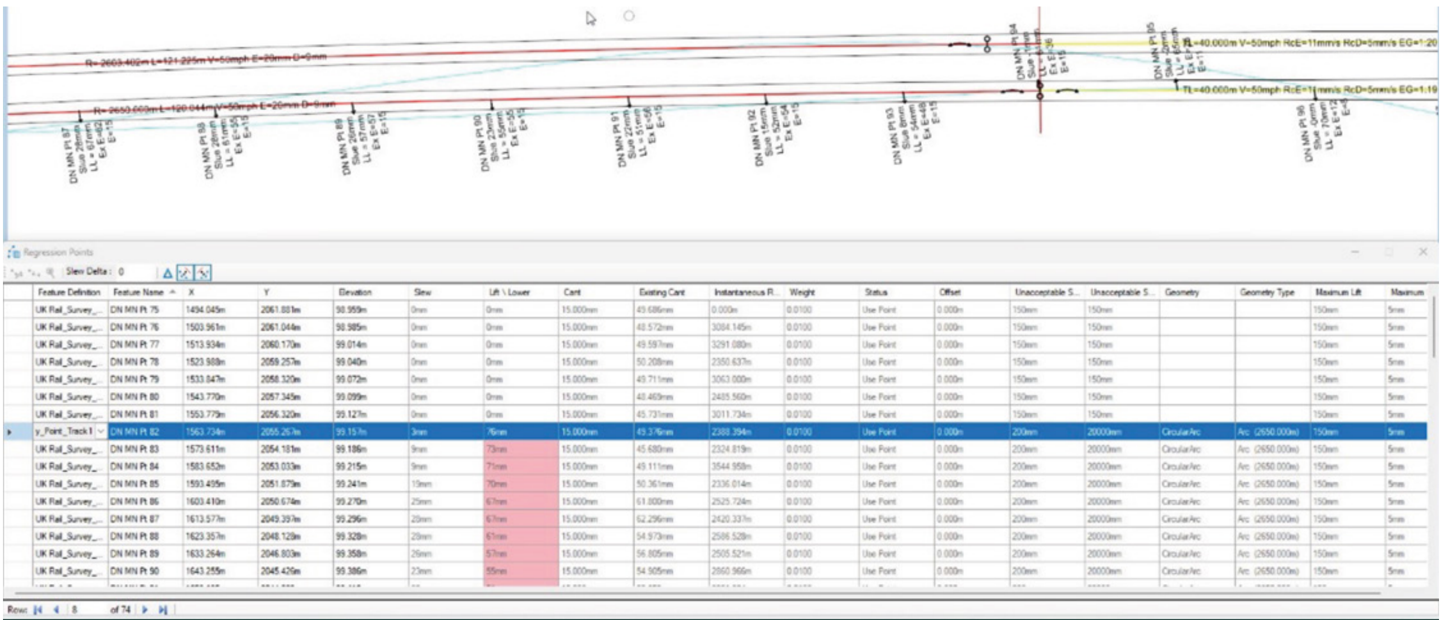

Figure 2: Survey and design review.

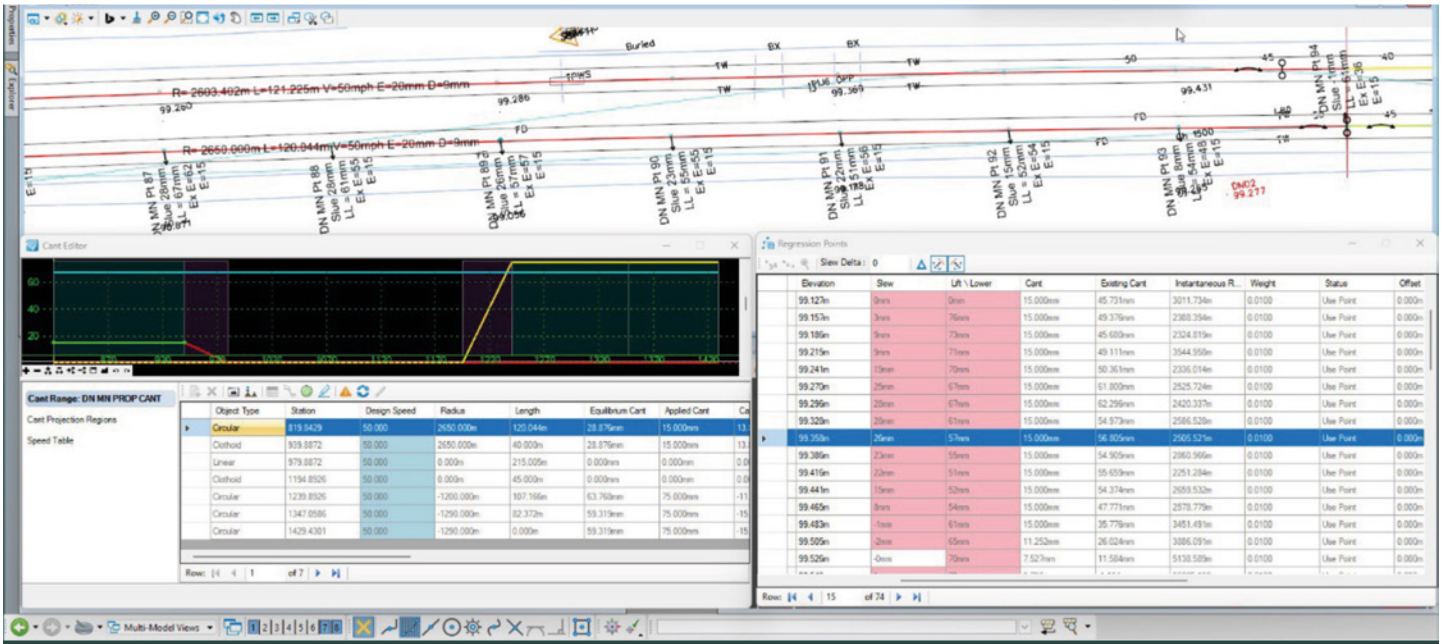

Figure 3: Geometry Model.

MORE EFFICIENCY AND LESS REDUNDANCY, GAINING VALUE FROM THE GEOMETRY MODEL

OpenRail Designer provides both graphical and tabular tools as shown in **Figure 3** for designers to quickly and efficiently evaluate multiple regression scenarios using geometry models. The geometry model is constructed using tangents (straight railway) and curve sets (combinations of transition curves and circular curves), both horizontally and vertically. While designers work in the familiar horizontal and vertical layouts, the software automatically combines them into a 3D geometric model of the track. Cant, the difference in elevation between the two rails, is applied to the geometric model so one rail is higher than the other through curves. Cant, a function of the curve radius, railway gauge, and speed, improves ride comfort and the distribution of loads across both rails. Railways trafficked by both faster and slower trains have mixed Cant requirements. For example, the required Cant for a freight train will likely result in poor riding comfort for a faster passenger train. This is where design of applied Cant and Cant Deficiency achieves a compromise to both accommodate the freight train and provide the riding comfort for the passenger train.

Geometry is also defined with chainage (or stationing), which is the distance from the start of the geometry. The chainage, elevation, perpendicular offset, and rotation relative to the bearing of the geometry is widely used to describe locations of trackside objects.

The geometry model is also fundamental for other railway engineering disciplines such as roadways, earthwork volumes, bridge and tunnel structures, signalling, and electrification. The OpenRail Designer geometry model is the single source of truth referenced by everyone. Because all disciplines are using the same geometric model, the risk of not having the latest changes is virtually eliminated allowing work to progress in parallel.

DRIVE COLLABORATION AND INFORMED DECISION-MAKING

Gain insights throughout the asset lifecycle

The railway geometry model is crucial to an efficient, modern, collaborative design environment. The renewal design will apply changes to the original design. Even if the changes are small, they may have a negative impact on other railway equipment. Any railway geometry changes may impact clearance tolerances, which need to be checked, and, in the worst case, need to be adjusted. A clearance issue found reviewing the model overlaid with trackside equipment is much easier and less costly to correct than if this issue is not found until construction.

The model can contain all the data. In addition to the railway geometry elements, it can contain related trackside equipment, asset identification, metadata, and much more. It becomes a true representation of the real world, otherwise known as a digital twin. In this case, a digital twin is a virtual representation of the railway, which can be composed of data from many different sources.

Traditionally, railway projects are delivered to construction as plan, long section, and cross section drawings as well as reports, schedules, and bills of materials. Uses of the deliverables are limited to the information the designer or drafter choose to include. Model-based or digital twin-based deliverables, on the other hand, empower the user to query the data they need when they need it. These can be traditional queries such as plan, long section, and cross section drawings or reports, but now the user can choose exactly what data to include in what area and interval.

Share the source model across disciplines and phases

Other railway engineering disciplines, such as signalling and electrification, are dependent on the geometry model. Any changes in the geometry model can result in changes to signalling and electrification that need to be reviewed and checked. For example, the location of the overhead line catenary wire in a curve needs to consider changes to the applied Cant in that curve. Any changes to the Cant will have three and a half to four times the radial effect on the contact wire, dependent on the contact wire height.

The design of the signalling system's pre-signalling point positions need to be calculated based on the line speed, vertical geometry gradients, and operating train's breaking characteristics. This is one of many design challenges where the geometry model directly constrains design outputs.

The renewal geometry model is also used for constructibility simulations, where the construction phases are planned and evaluated to determine the most efficient implementation as well as analysis of any challenges. Status information of the geometry model elements, what should be replaced, and what should be modified are fundamental information to the planning of construction phases.

Sharing the original source geometry model within the project is one of the most important aspects of a collaborative multidisciplinary design environment. To further support sharing the geometry model, project participants need to know what the latest version is and what changes are made between versions. Secure data governance of today's engineering work-in-process documents including federated models, references, and versions, along with digital twins, is critical to efficiently managing these powerful data rich environments.

Figure 4: Visualize designs in real world context.

Turn data to insights with a railway digital twin

Since digital twins are computer software agnostic, different data can contribute to enhancing them. As different models, processes and systems are fed into the digital twin over time, it becomes a true virtual representation of the current, and past, conditions suitable for operational monitoring, maintenance, and future development.

Reviewing a digital twin usually does not require any specialist software, which makes it easy and quick to access. For example, the Bentley Infrastructure Cloud is a cloud based digital twin environment fed from OpenRail Designer where users can project models and plan sheets from anywhere with internet access.

Plan, profile, and cross section views, supported with reports and visualizations such as shown in **Figure 4**, can be extracted at any position from the 3D model-based digital twin as needed. Digital twins are scalable to serve the lifecycle of an asset, so a railway digital twin can start with rail geometry, related track corridor equipment, and a terrain model, and can grow over time as the railway is constructed, put into service, and maintained.

DELIVERING SAFE, RESILIENT RAIL NETWORKS

The way we design and deliver contracts, as well as the way we plan our infrastructure, needs to change so that we can deliver the kind of modern, sustainable, and safe transportation systems that our communities need.

The rail industry stands to gain immense benefits from digital innovation throughout the asset lifecycle. Data is the foundation of infrastructure intelligence, and digital twins are the key to unlocking engineering data from files to be analysed and reused across the lifecycle. OpenRail Designer creates models that are easily fed into a digital twin.

Digital innovation can support the achievement of sustainability targets and provide a better service to infrastructure end users, including increased passenger and freight services. Embracing technologies, such as big data, the Internet of Things, and digital twins, together with artificial intelligence and machine learning techniques, enable engineers to collaborate in real time, evaluate the impact of changes more seamlessly, and significantly reduce rework and errors to deliver safer and more resilient projects in less time.

TEAMWORK IS MAKING THE DIGITAL RAIL INDUSTRY A REALITY TODAY

The PWI, several PWI member organizations, and Bentley have been working together for the past 18 months improving the efficiency of track design, regression, and review workflows using OpenRail Designer. Thanks to this fantastic partnership, the rail industry is better prepared to deliver the traditional project deliverables of today and digital deliverables of tomorrow at the same time with a single effort.

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