CASE STUDY

JLP Delivers Railway Tunnel Clearance Modifications at a Fraction of the Cost

Bentley's Rail and Transit Solution Enables Rapid 3D Modeling, Analysis and Design while Minimizing Impact on Business Operations

Project Summary

Organization:
J.L. Patterson & Associates

Location:
Washington, United States

Project Objective:
- Achieve the fastest, most cost-effective, solution to increase tunnel clearance
- Survey tunnel and perform modifications with minimum impact on operations
- Minimize construction time and cost

Products used:
Bentley Pointools
MicroStation
Bentley Rail Track

Fast Facts

- LiDAR technology and Bentley software was used to survey and analyze tunnel interior
- 3D model of tunnel interior and existing track alignment
- Analysis of 3D model allowed JLP to develop optimal tunnel-modification recommendations
- Tunnel modifications completed in weeks rather than months

ROI

- Surveyed tunnel with minimal disruption to business operations
- Solution reduced the amount of tunnel surface material to be removed from 177 to 8.3 cubic feet
- Cleared tunnel for container traffic at one-tenth of the original USD 10 million cost estimate

The Cascade Tunnel, the longest railroad tunnel in the United States, is 7.8 miles long. Built between 1925 and 1929 near Stevens Pass in Washington State, this single-track tunnel was designed to reduce the route length for trains by 8.7 miles and eliminate 21 miles of 2 percent or steeper grade. In 1989, railroads operator BNSF effected a tunnel clearance program by notching the tunnel's roofline to allow double stack intermodal trains to operate through it. Normal track structure movement caused trains to strike the underside of the tunnel making it necessary to revisit tunnel clearance. Given its high utilization, surveying of the tunnel using conventional manual methods was impossible.

Identifying Tunnel Impact Points

BNSF has been monitoring sporadic clearance events or strikes for a number of years. However, the frequency and severity of strikes caused BNSF to take a much closer look at the source of the problem. Management presumed that problems were the result of poor horizontal track alignment with notches added to the very top of the tunnel in 1989 as part of the clearance program. However, to fix the problem they needed to identify exactly where these impact points were and make necessary changes to the tunnel clearance.

To do this, the company hired J.L. Patterson & Associates (JLP). "We needed detailed knowledge about the interior of the tunnel," explained Marc Canas, vice president at JLP. "But we couldn't use conventional tunnel survey methods because of the heavy traffic and time constraints. Engineering and surveying crews are limited to no more than 1- to 2-hour access windows at any given time. With these access constraints, it would have taken us weeks using conventional survey methods to model the interior of the tunnel and determine the clearance optimization plans." Furthermore, BNSF Railways wanted to minimize cost and project scope. Its early estimate of the project indicated that fixing the problem would require notching the tunnel for 177 cubic yards – a project that would cost approximately USD 10 million, require several months of construction, and seriously impact operations.

Capturing Data While Minimizing Business Disruption

JLP partnered with a mapping sub-consultant that used LiDAR technology and Bentley Pointools and MicroStation to analyze the existing alignment of the track inside the tunnel and model the tunnel's interior surface. JLP used Bentley's point-cloud solutions to quickly survey the entire tunnel, analyzing the data to determine the required modifications before making the necessary structural changes to the tunnel. "We equipped a high rail vehicle with a global positioning system (GPS) and an inertial measurement unit (IMU)," explained Canas.

"As the vehicle traversed the tunnel, it captured point-cloud data needed to create a 3D model of the tunnel's internal surface, the precise center line of track, and the precise location of the existing notches in the tunnel." The team established horizontal and vertical survey controls with targets placed at each portal, as well as a control target along the tunnel at approximately 1,500-feet spacing. The control points and inertial navigation data were used to determine the smoothest, best estimate trajectory of the three dimensional route of the mobile mapping system.

Creating a 3D Model to Determine the Optimal Solution

Analyzing several million data points captured using Bentley software – more than 2 gigabytes of point-cloud data – JLP developed the digital 3D model, analyzed it, and prepared proposed alignment modifications that would minimize clearance conflicts while maintaining the alignment within

> *"Bentley has long been an essential component of our engineering toolbox on Cascade Tunnel enabling us to design and clear the tunnel for container traffic at one-tenth of the cost."*
>
> *— Marc Canas, vice president, J.L. Patterson and Associates*

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tolerances for tangent track. JLP also identified tunnel soffit modifications in the areas of conflict between the clearance envelope and the crown of the tunnel that would remain once the track alignment adjustments were made.

"Bentley software allowed us to model the tunnel without affecting operations in this busy corridor," commented Canas. Using this 3D model, JLP developed proposals for:

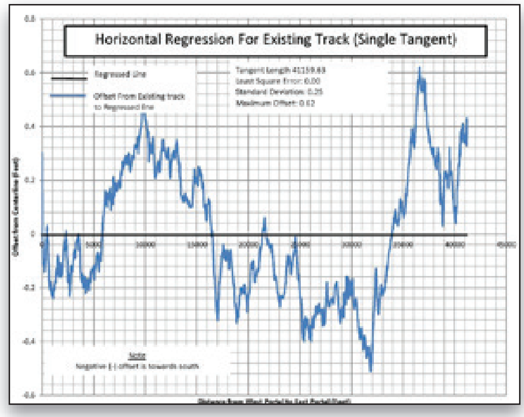
- The "best fit" track alignment to match the existing notch location
- Additional notching required within the tunnel to line up with the existing track alignment
- The best fit track alignment with tangents and small angle breaks, while minimizing proposed notching

Because JLP had such a detailed and complete 3D model of the tunnel interior and track, proposals were very accurate and exact. "The tunnel was analyzed using the desired clearance envelope, the track cross level was accounted for, and then we calculated the area of cut with no track realignment," explained Canas. "We determined we needed to make 177 cubic yards of cut to meet the clearance envelope parameters." However, by using the powerful regression tools within Bentley Rail Track, designers were able to develop a track alignment with tangents and small angle breaks that enabled the 25-miles-per-hour operational speed to be maintained while significantly reducing cut.

Realizing the Benefits

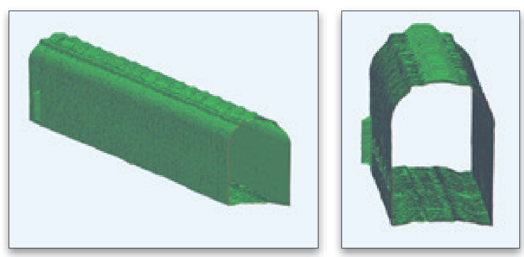
The geometric results of the proposed track realignment yielded fantastic results. "We were able to minimize corrections to the tunnel clearance envelope to just 8.3 cubic yards of excavation, saving a tremendous amount of time, maintenance funding, and operational disruption," explained Canas. "Bentley software was pivotal in saving BNSF Railways tremendous time, money, and effort by reducing the amount of cut, improving operations and minimizing disruptions to this very busy line in the system. Using Bentley's innovative solutions, we found a better way to address the problem – an approach that would cost about USD 1 million, approximately 10 percent of original estimates, and cut construction time to weeks instead of months.

"The Cascade tunnel project is unique because it's the first time that software has been used to minimize work in the field," concluded Canas. "The proposed solutions prior to our involvement included very expensive propositions such as excavating inside a busy tunnel and realigning the tunnel itself. But we collected accurate information from inside a 7.8-mile-long tunnel using LiDAR technology and powerful tools from Bentley – and were able to design and clear the tunnel for container traffice at a fraction – specifically, one-tenth – of the cost."



Horizontal regression of existing track alignment with +ve and –ve offsets from centerline.

Cascade Tunnel portal showing existing notches and impact points.



3D PDF showing point cloud of tunnel surface with existing notches visible at top.