Project Summary

Organization:
London Underground Ltd

Solution:
Rail and Transit

Location:
London, United Kingdom

Project Objective:

- Safely replace the deteriorating tunnel lining over a 215-meter section of the Jubilee Line.
- Maintain operational tunnel infrastructure without detrimental consequences to the safe running of passenger trains.

Products used:
AECOsim Building Designer, Bentley Descartes, Bentley Navigator, Bentley Pointools, Bentley View, MicroStation, and ProjectWise

Fast Facts

- ProjectWise helped LUL build a cohesive team and leverage the collective intelligence of the group.
- Bentley software allowed the project team to deliver a robust solution through the application of virtual design and value engineering.
- The Bond Street to Baker Street Tunnel Remediation Project won the "Greatest Contribution to London" accolade at the London Civil Engineering Awards 2014.

ROI

- Bentley 's 3D technology improved planning, design, and assurance efficiencies resulting in time savings of up to 20 percent, the recycling of 92 percent of all tunnel lining removed, and the safe reuse of 77 percent of tunnel equipment assets.
- Commissioning two segment handling plants (SHP) doubled productivity and contributed to the tunnel relining being completed four months ahead of schedule.

London Underground Underpins Planning, Design, Assurance, and Construction Processes with Bentley's 3D Technology

Jubilee Line Remains Operational while London Underground Replaces Tunnel's Lining

Models Propel Project

The London Underground Ltd (LUL) Bond Street to Baker Street Tunnel Remediation Project undertook the safe replacement of deteriorating expanded precast concrete (EPC) lining with a spheroidal graphite iron (SGI) lining in a 215-meter tunnel segment on the Jubilee Line—while it remained fully operational. The major challenge of this GBP 34 million project was to maintain functional tunnel infrastructure without detrimental consequences to the safe running of passenger trains. LUL initiated this project with an ambitious target of 20 percent cost reduction by improving planning, design, and assurance efficiencies.

AECOsim Building Designer, Bentley Descartes, Bentley Pointools, Bentley Navigator, and ProjectWise enabled collaboration and supported creation of a geospatially accurate, fully coordinated 3D model. With the use of Bentley technology for 3D visualization and animation, 4D planning, 3D printing, and virtual reality, all stakeholders and decision makers understood the design and project intent without ambiguity. LUL realized time savings of up to 20 percent by starting design and assurances processes earlier in the project lifecycle—made possible, in part, by the early creation of a 3D laser scanned model of the project site.

Passenger Safety, Convenience

Carrying 240 million passengers per year, the Jubilee Line is an essential link in the underground railway network serving Central London (West End) and Canary Wharf (Financial District). LUL operates a service of 30 trains per hour during morning and evening peak travel times. The original tunnel lining along the Bond-to-Baker Street stretch was installed in the 1970s and had begun to deteriorate, causing potentially unsafe conditions. Closing a major section of the line for repairs would have taken trains out of service for months, and postponing repairs would have increased the risk of tunnel integrity failure during passenger traffic hours. The preferred solution was to undertake the tunnel relining project while maintaining fully operational infrastructure. Preventing the disruption or inconvenience of passenger travel was paramount, with LUL aiming to support the continued safe running of 30 trains per hour, without the need for speed restrictions.

The scope of work was extensive. Foremost was safely replacing the EPC tunnel segment lining with SGI lining. Pre- and post-site enabling works had to be erected to reroute, relocate, and reinstall all the infrastructure required to keep the line running during passenger traffic hours. Preventive measures also had to be taken to mitigate movement, which involved tunnel segment structural support strapping.

This work had to be done in the minimum amount of time, with minimal noise vibration or environmental effects. The EPC tunnel lining segments were to be replaced during engineering hours, which were limited to 2.5 hours per night. All materials, construction personnel, plant equipment, and removed EPC segments had to be transported to and from the single bore tunnel before passenger traffic resumed.

An Inside Job

To ensure the project was conducted to the satisfaction of all stakeholders—including the mayor's office, Transport for London, industry regulators, and the press and public—LUL decided to undertake the design, assurance, project management, and construction in-house. It was an opportunity to uphold LUL's reputation and demonstrate a standard of excellence in the industry.

Original tunnel lining installed in the 1970s showed signs of water ingress, causing potentially unsafe conditions.

"Bentley software solutions helped LUL build a cohesive, collaborative design, assurance, and construction delivery team, allowing us to leverage the collective intelligence of the group. The software ensured that we were able to manage uncertainties inherent in today's complex infrastructure projects, and deliver with confidence."

— Garry Pratt, Project Manager, Bond Street to Baker Street Tunnel Remediation Project, London

LUL began this highly visible and extremely ambitious project with the additional goal of delivering significant improvements in project delivery, on schedule, and within the agreed budget. LUL also had to leverage information technology to lower costs by as much as 20 percent from planning and design through asset management. Bentley's 3D modeling and visualization software allowed the project team to meet this goal and deliver a robust solution for the tunnel relining process. The innovative design was a self-sufficient mobile traveling worksite that was capable of carrying out the segment replacement using a mechanized plant. LUL's project design team developed the concept and implemented the design, assurance, and commissioning of the train-mounted segment handling plant (SHP), which moved equipment and works in and out of the worksite.

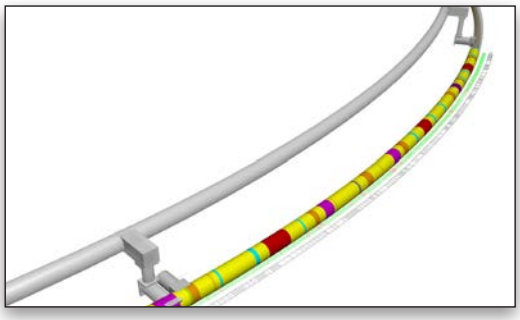
To maximize interoperability and use of project data between disciplines, LUL used ProjectWise in combination with Bentley's 3D modeling software. The result was a more streamlined design and assurance process, with improved project team and stakeholder collaboration, greater information control and distribution, and fewer errors. The 3D technology enabled planners, construction designers, and safety teams to visually and spatially evaluate the wagon. This allowed them to revise the equipment, tasks, processes, and activities with greater insight and less ambiguity.

3D Visualization

The application of knowledge, skills, and techniques combined with Bentley software solutions enabled LUL to achieve effective and efficient project delivery. ProjectWise provided a single, unified data environment for creating, sharing, managing, and assuring the quality of project information, helping to build a cohesive team, and allowing LUL to leverage the collective intelligence of the group to make informed decisions and achieve superior results. The ProjectWise Rules Engine supported the business processes for collection, coordination, verification, and control of both graphical and non-graphical data defined within BS 1192. Using this British Standard, which includes a common methodology for managing data produced by and between all parties, allowed the project team to easily gather, interpret, and transmit design information using approved workflows.

Using Bentley software for 3D point-cloud scanning and surveying (Bentley Pointools and Leica CloudWorx for MicroStation), 3D modeling (MicroStation), and 4D planning and sequencing (Bentley Navigator) enabled the project team, stakeholders, and the public to visualize and understand how the tunnel lining replacement would be successfully accomplished. Interactive 3D PDFs, i-models, 4D animation sequences—even a physical scale model of the tunnel and SHP wagon generated with 3D printing technology—all contributed to timely feedback and modification of project plans, helping LUL avoid potential extra costs and delays associated with late-stage changes.

A number of 3D models were created from as-built records, supplemented by data generated from laser scan surveys. Put together, the integrated model helped minimize the risk of clashes and provided the tools for continuous review and testing of the design for constructability, maintenance, and operation. This model will ultimately provide LUL with an accurate record of assets for use in managing the relined tunnel section throughout its lifecycle.



i-models, 3D PDFs, and 4D simulation contributed to full understanding of the design and project intent.

Real ROI

Using Bentley's visualization software to virtually explore, review, and manipulate the designs engendered confidence that the correct solutions had been chosen to ensure project success and achieve business goals. The multimedia format was critical to securing decisions in favor of the project from high-level decision makers, including the London Mayor's office, London Assembly's transport committee, Transport for London's chairman and commissioner, among others.

Time savings of up to 20 percent were realized because design and assurances processes were started earlier in the project lifecycle, resulting in a highly coordinated solution during project development. Visual and virtual design review allowed the project team to validate designs more quickly, eliminate late-state design changes, resolve complex construction details before pre- and post-site enabling works, and reduce design errors and omissions. The decision to commission two SHPs so the tunnel could be relined from both ends doubled productivity and contributed to relining being completed four months ahead of schedule.

Bentley software allowed the project team to consider and execute planning tasks in ways that reduced safety to "As Low As Reasonably Practicable" (ALARP), as well as provide supporting data that operational safety and assurance were compliant. Being able to perform 4D project task information modeling in Bentley Navigator revealed any safety risks. Running what-if scenarios and time motion studies allowed the project team to adjust tasks to achieve accurate, realistic, and safe scheduling. These activities reduced planning, risk assessment, safety, and assurance costs by 15 percent.

Contribution to London

In recognizing this project for its great contribution to London, judges for the London Civil Engineering Awards 2014 noted: "This project is a true demonstration of teamwork, dedication, and continuous improvement, and shows a massive leap in engineering ingenuity." LUL's project delivery team attributed its success, in part, to employing Bentley's 3D technology, which was the underpinning for project design, assurance, planning, and construction processes.

Find out about Bentley at: www.bentley.com

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