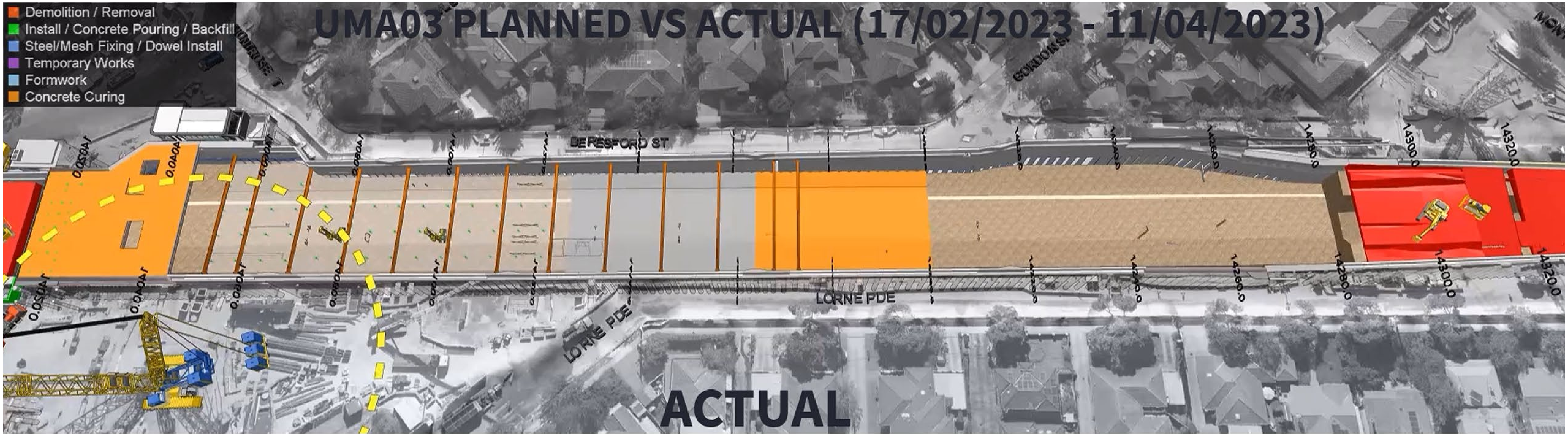
Digital Twins

Delivering results in design, construction, and operations

Bentley®

Table of contents



Introduction

Digital twins have redefined what's possible in infrastructure. Across design, construction, and operations, infrastructure professionals are using digital twins to cut costs, boost efficiency, reduce risk, lower carbon emissions, and optimize asset performance.

The results speak for themselves:

- SPL Powerlines UK, a rail infrastructure specialist, successfully delivered 146 kilometers of new overhead-line infrastructure on time and under budget by using a digital twin to detect potential design conflicts and safety issues.[1]
- Proicere Digital, an infrastructure consultancy, saved GBP 80 million in costs and 500 days (and counting) of construction rework by leveraging a digital twin in its work to modernize a U.K. nuclear waste treatment facility.[2]
- Qk4, a civil engineering and planning consulting firm, saved Kentucky taxpayers over USD 300 million using a digital twin to reduce bridge survey time by more than 50% and accelerate critical infrastructure repairs across the state.[3]

1 "SPL Powerlines UK enhances multidiscipline digital workflows to develop 447 kilometers of overhead electrified lines," Bentley Systems case study, 2024. https://www.bentley.com/wp-content/uploads/cs-spl-powerline-overhead-lines-ltr-en-lr.pdf.

2 "Proicere Digital Delivers Modern Nuclear Waste Treatment Facility to House World's Largest Civil Stockpile of Plutonium," Bentley Systems case study, 2025. https://www.bentley.com/wp-content/uploads/cs-proicere-ltr-en-lr.pdf.

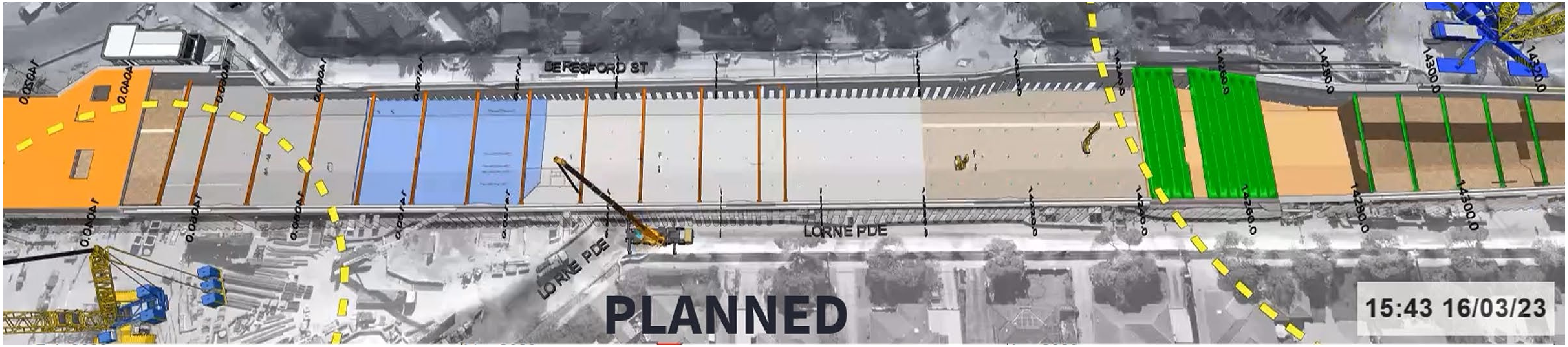
3 "Qk4 Revolutionizes Bridge Survey Program, Saving Kentucky USD 300 Million," Bentley case study, 2025. https://www.bentley.com/wp-content/uploads/cs-qk4-bridge-ltr-en-lr.pdf.

Across the infrastructure lifecycle, digital twins provide dynamic, virtual representations of physical assets—planned or existing—that reflect their condition at any point in time. By combining and leveraging data from various sources, including geospatial context, 3D models, IoT sensors, and operational records, they deliver situational awareness to enable effective responses to current conditions. When paired with advanced analytics or simulation, they also help infrastructure professionals more confidently plan for the future. And when shared across the asset lifecycle, digital twins reduce the risk of information loss as projects move from design to construction and, ultimately, to operations.

In the past few years, tech advances have made digital twins accessible, scalable, and cost-effective—driving adoption throughout the world's infrastructure. A Bentley survey found that over half of infrastructure professionals already use digital twins in some projects.[4] At the same time, KPMG ranks them among the top 10 trends shaping infrastructure.[5] This momentum reflects broader global adoption, with digital twin market size projected to grow at a CAGR of roughly 40% over the next decade.[6]

What does success with digital twins look like in practice? This report explores how digital twins are being used at every stage of the infrastructure lifecycle, bringing clarity to infrastructure complexity and delivering measurable impact. It also looks ahead to how digital twin capabilities are expected to evolve and outlines practical steps for design, construction, and operations firms to begin their digital twin journey.

4 Represents responses from 2,000 infrastructure professionals (C-suite, director, and users) globally across 21 industries.
5 "The Great Reset: Emerging Trends in Infrastructure and Transport," KMPG, 2025. https://assets.kpmg.com/content/dam/kpmgsites/xx/pdf/2025/02/emerging-trends-in-infrastructure-and-transport-2025.pdf.coredownload.pdf.
6 *Digital Twins Market*, Fortune Business Insights, 2024. https://www.fortunebusinessinsights.com/digital-twin-market-106246.



IMAGES COURTESY OF LAING O'ROURKE

From concept to constructability

Improving design accuracy and coordination

Designing infrastructure requires project teams to balance engineering precision with real-world constraints. Too often, design firms use fragmented systems and disconnected workflows, creating delays, rework, and costly errors.

What happens when design shifts from relying on a patchwork of inputs to leveraging a unified, synchronized digital twin?

By connecting design models, geospatial location data, project documentation, engineering analytics, and more, digital twins create a dynamic, interactive view of the asset. This visibility enables engineers, architects, and stakeholders to rapidly explore a design's feasibility, resilience, constructability, and sustainability—from initial concept through construction handoff.

Teams can visualize and simulate how an asset will interact with terrain, existing infrastructure, and environmental factors. This helps them evaluate how designs will hold up under real-world conditions and identify ways to maximize the asset's long-term viability. It also enables them to locate and resolve design clashes before they lead to delays—and before breaking ground.

With shared access to the same unified view, various teams can align earlier and rapidly iterate with stakeholders to shorten feedback loops. And because digital twins can incorporate different data types and formats across the diverse tool sets designers use, they can streamline workflows for greater productivity.

In the pages that follow, we share three examples.

Common design phase challenges

- Designing for real-world conditions
- Gathering stakeholder input
- Ensuring compatibility across tool sets
- Validating designs and constructability before breaking ground

Case study

Designing for real-world conditions

I-95 Rappahannock River Crossing

IMAGES COURTESY OF JOHNSON, MIRMIRAN & THOMPSON, INC.

IMAGES COURTESY OF JOHNSON, MIRMIRAN & THOMPSON, INC.

Site conditions, environmental regulations, utility conflicts, community impacts, and long-term operational needs all shape how projects take form. For the Virginia Department of Transportation, successfully upgrading one of its most congested corridors—the span of Interstate Highway 95 crossing the Rappahannock River in Northern Virginia—meant ensuring the design could stand up to on-the-ground realities. Many attempts had previously been made to improve the river crossing in the past, but all failed to materialize because of political, environmental, or historical considerations.

The project aimed to increase southbound capacity on I-95 at the Rappahannock River. The plan included creating six miles of new southbound lanes, converting the original lanes into a collector-distributor road, and constructing four new bridges over the Rappahannock River.

To support this work, the lead designer, Johnson, Mirmiran & Thompson, created a digital twin to model the project at a granular level of detail. The digital twin included scalable 3D meshes of the terrain, enabling the team to explore accurate representations of ground conditions. Project teams and stakeholders could easily view models of the new roadways and bridges in their geospatial context, enabling them to evaluate the design's impact on traffic flow, safety, and sustainability early in the process and identify potential issues before they became costly delays.

Additionally, by creating immersive simulations and animations of traffic changes and work zones, the team could give decision-makers at 10 federal and local regulatory agencies a clear view of how the design addressed environmental and operational concerns. This helped the organization effectively navigate the complex environmental sensitivities and requirements while ensuring the project met its timeline and performance goals.

The I-95 Rappahannock River Crossing was delivered on time.

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Case study

Gathering stakeholder input

Midland Main Line Electrification Program

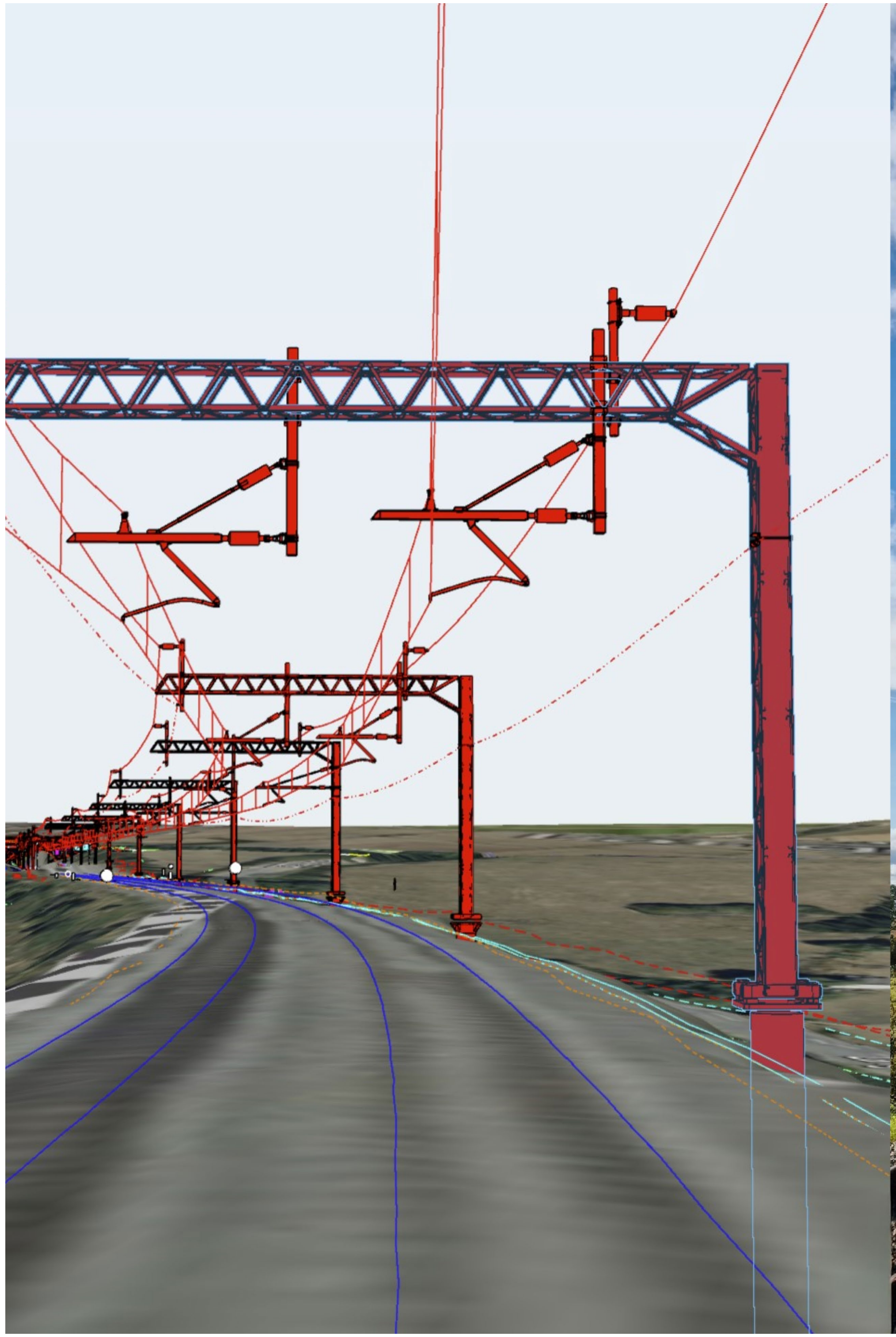
IMAGES COURTESY OF SPL POWERLINES UK LTD.

The Midland Main Line Electrification (MMLE) program is a large infrastructure project spanning central England, known as the Midlands. The project involves electrifying the railway line from London to Sheffield, requiring the installation of new overhead lines through Bedford, Nottingham, Sheffield, Leicester, and Derby. With more than 20 design organizations involved, coordinating designs and integrating new systems into the existing rail infrastructure posed a significant challenge.

To support early-stage collaboration across stakeholders and design teams, SPL Powerlines UK deployed a digital twin that combined design models, high-quality drone imagery, and asset location data. This digital twin became a central source of truth for the project, enabling distributed design teams and a broad range of stakeholders to engage effectively from the outset of the project's design phase.

Importantly, the digital twin allowed stakeholders—including those who don't typically engage with engineering models—to visualize proposed infrastructure, assess spatial relationships, and provide actionable feedback before designs advanced to construction. Users could also perform tasks in the digital project environment that would traditionally have required a site visit. This reduced the need for site visits, accelerated design reviews, and helped ensure right-first-time installation. Using the digital twin, SPL Powerlines UK successfully delivered 146 kilometers of new overhead-line infrastructure on time and under budget.

IMAGES COURTESY OF SPL POWERLINES UK LTD.



The MMLE program completed 146 kilometers of overhead lines on time and under budget.

IMAGES COURTESY OF SPL POWERLINES UK LTD.

Case study

Validating designs and constructability before breaking ground

NYSDOT 138th Street Bridge

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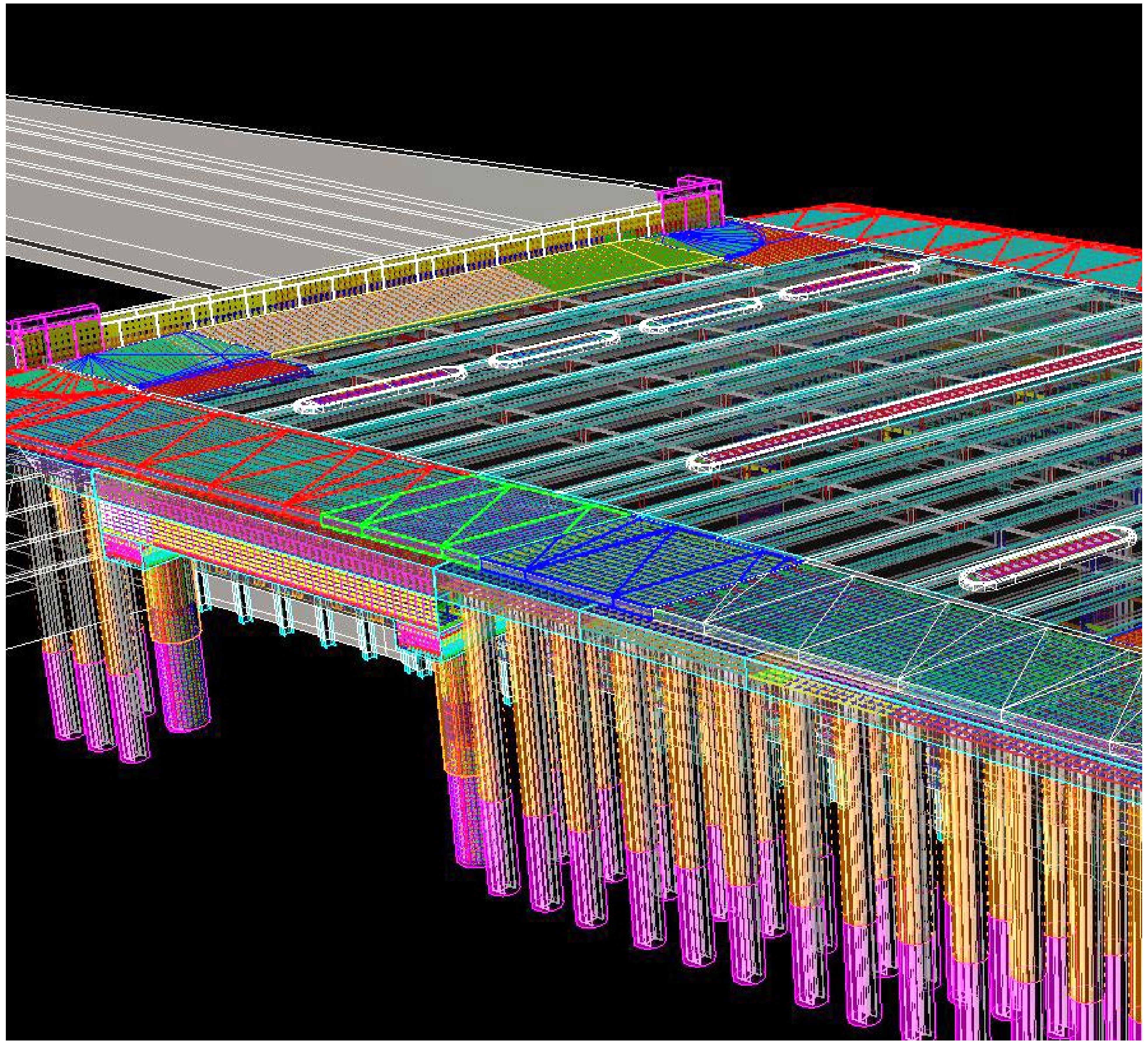
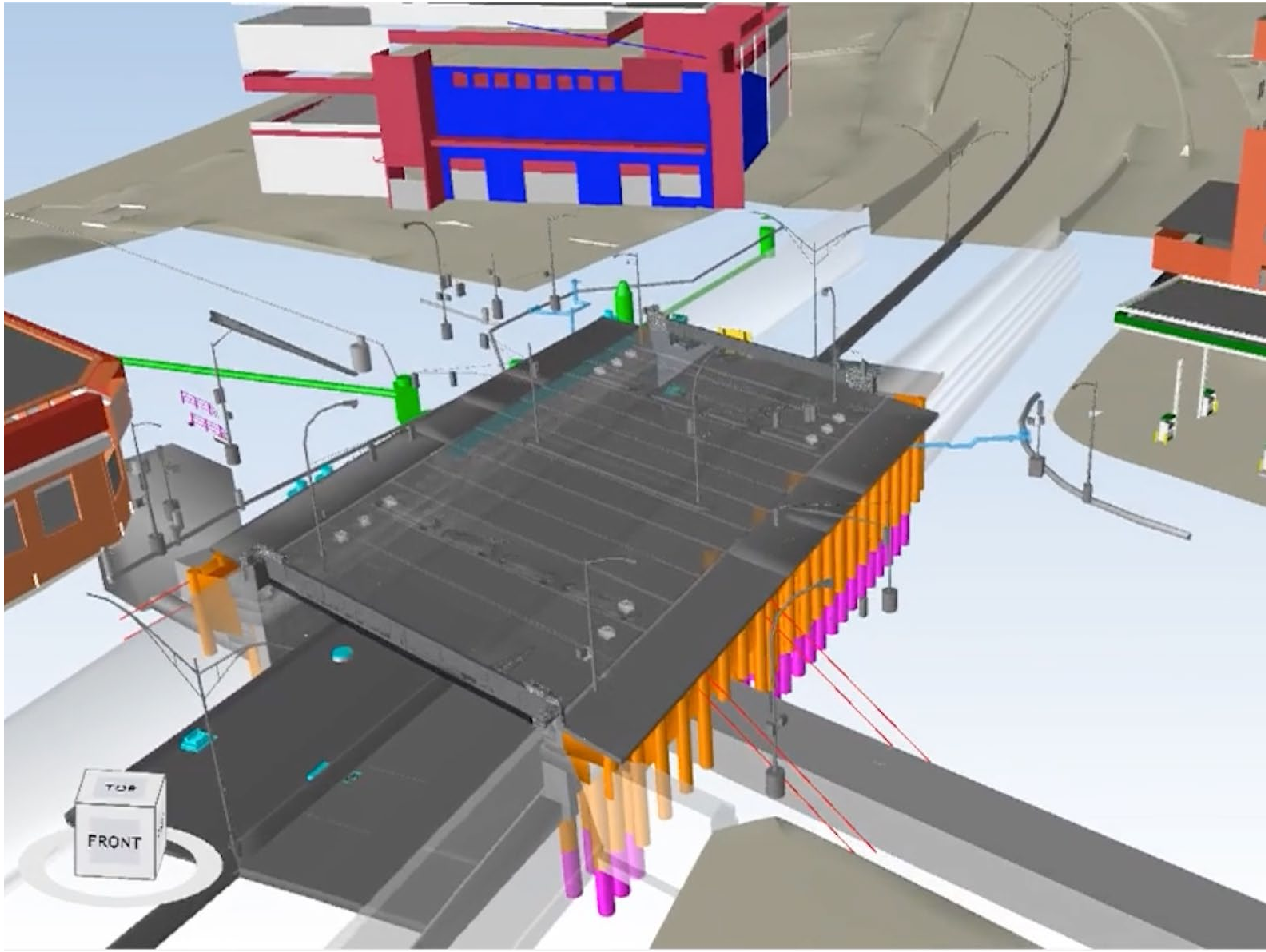


The East 138th Street Bridge in the Bronx is a vital artery, carrying over 150,000 vehicles daily. It connects neighborhoods, supports pedestrian access, and serves as a key route in the New York City Marathon. Though the bridge is compact in length, replacing the aging six-lane structure proved challenging because of complex traffic, utility, geotechnical, and structural design issues.

To manage these challenges, the New York State Department of Transportation (NYSDOT) developed a highly detailed digital twin of the structure and its surroundings. The model served as the legal contract document and enabled engineers to confirm constructability well before work began. A simulation of the superstructure and pedestrian components allowed the team to test structural design assumptions and address geometric constraints to ensure that the final design was safe and aesthetically pleasing, and that it blended into the existing features around the bridge.

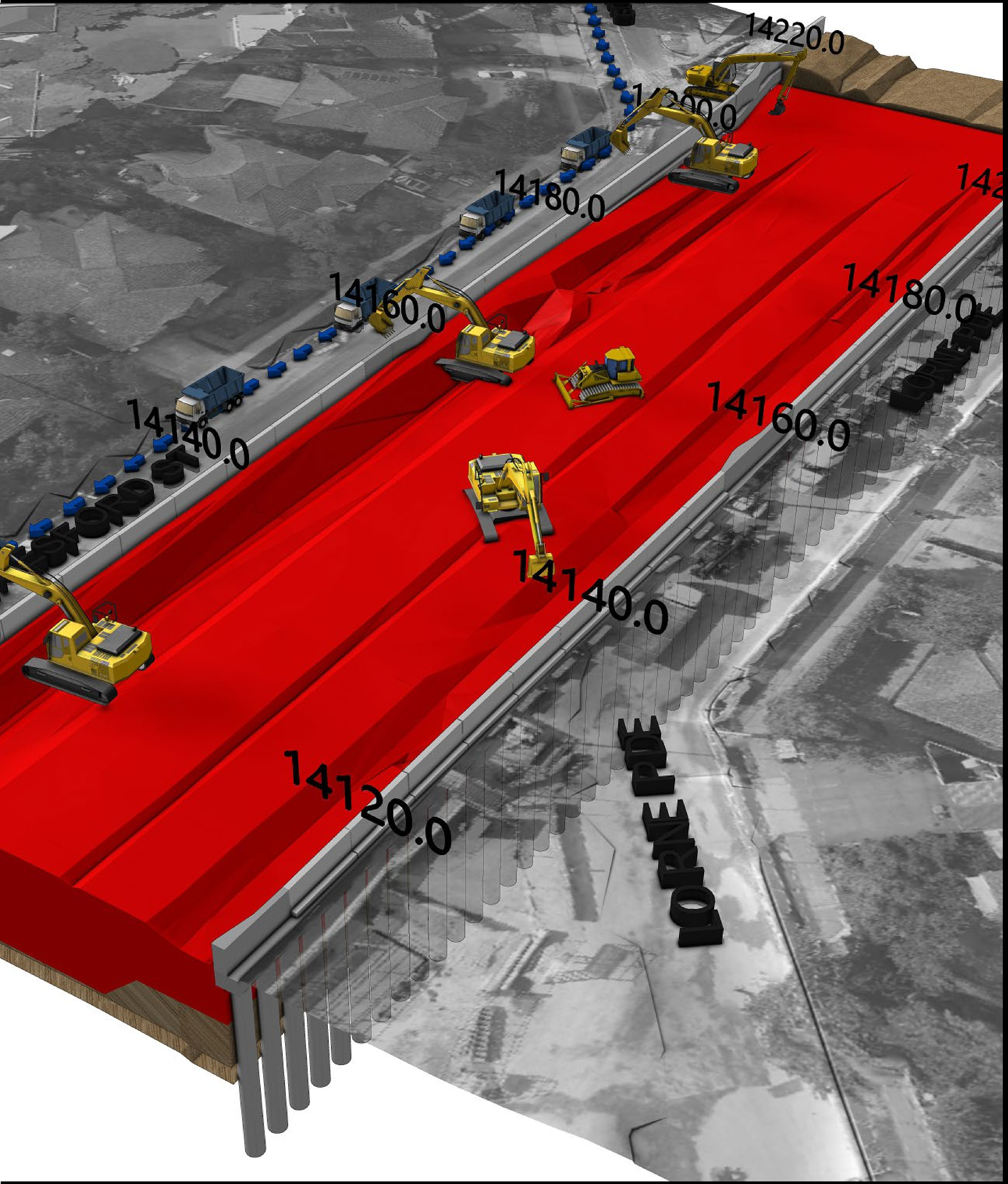
By validating design feasibility and buildability before breaking ground, NYSDOT avoided costly redesigns and construction delays. Additionally, providing contractors with a fully coordinated model as the legal contract enabled them to visualize complex site conditions and submit more accurate bids. As a result, the winning contract came in 15% below the original estimate.

IMAGES COURTESY OF NYSDOT



NYSDOT avoided costly redesigns and construction delays.

IMAGES COURTESY OF NYSDOT



IMAGES COURTESY OF LAING O'ROURKE

From breaking ground to completion

Reducing construction time, cost, and risk

Construction teams must often coordinate complex schedules, budgets, materials, logistics, and safety measures across multiple contractors, agencies, and suppliers. However, when information is fragmented across disparate systems—and not easily accessible by all participants—small changes can cascade into costly delays, safety risks, miscommunication, and even construction defects.

Digital twins unify and visualize asset specifications and site conditions with scheduling, cost, compliance, and environmental data to enable teams to rehearse the construction sequence and logistics before breaking ground. This is critical for proactively identifying safety, logistics, and scheduling risks. It also enables more effective collaboration among construction teams, suppliers, and agencies.

With digital twins, teams don't have to rely on printed plans or outdated PDFs. Instead, they can access up-to-date, high-quality engineering data from any location—ensuring alignment with the latest plans, schedules, and specifications. As materials, crews, and equipment shift across locations, digital twins make optimizing and tracking resources easier. And rather than managing as-built documentation retroactively, teams can use digital twins to capture what's been built and when and how it was built—across dozens of projects—for accurate recordkeeping.

Let's take a look at three examples.

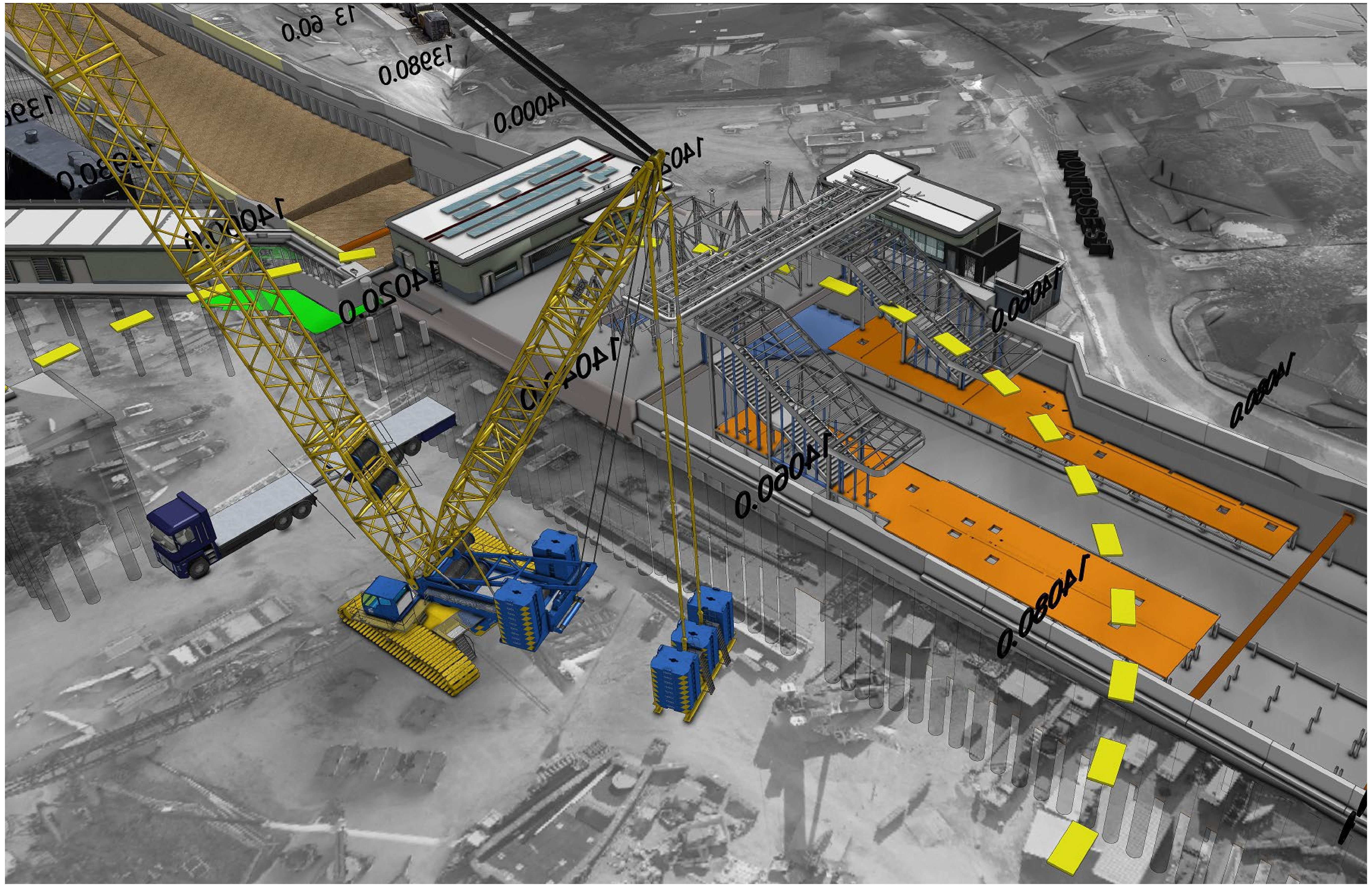
Common construction phase challenges

- Managing construction risks in safety, logistics, and scheduling
- Accessing high-quality engineering data in the field
- Enabling accurate as-built documentation and recordkeeping
- Tracking and optimizing complex resources

Case study

Managing construction risks in safety, logistics, and scheduling

SEPA Surrey Hills Level Crossing Removal Project



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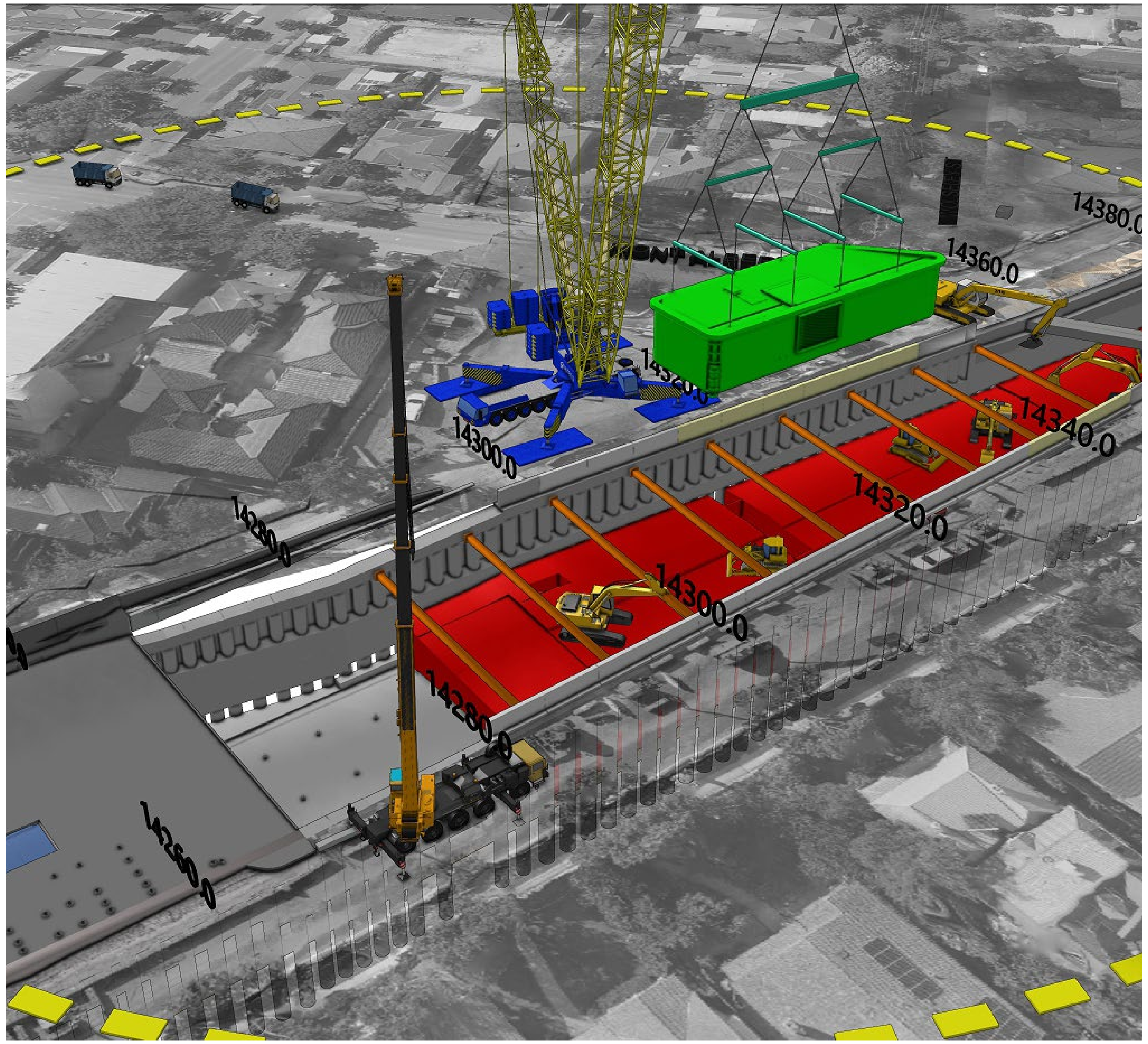


Rail networks inevitably cross paths with roads. Many of these intersections in the Australian state of Victoria are level crossings, meaning the roads and railways intersect at ground level. Although these crossings are easy to develop, they pose safety and logistical challenges. They can bring road travel to a halt for long periods as lengthy trains pass by, and they can create the risk of trains colliding with cars or pedestrians.

To address this, the Victoria government launched an ambitious initiative to eliminate 85 level crossings, which included lowering the area's railway into a trench and constructing overpasses to alleviate traffic congestion.

To better manage road and rail traffic disruptions during construction, Laing O'Rourke Construction, working with the South Eastern Program Alliance (SEPA), used a design for manufacture and assembly (DfMA) approach. Instead of being built at the site, major structural components would be manufactured off-site and then moved to the project area for installation. Using a digital twin, construction teams could visualize the project and clearly anticipate potential safety, logistical, and scheduling issues. The digital twin combined 3D terrain data created from drone imagery with 3D models of the railway, station, and other associated assets. This highly accurate virtual representation of the project limited the need for on-site measurements, reduced worker hazards, and saved time. Moreover, by integrating project schedules within the digital twin, the project team developed construction staging plans more than 70% faster than with 2D diagrams and lowered the risk of clashes by 75%.

As they monitored development progress within the digital twin, teams could quickly and easily identify which elements were behind schedule and which were ahead, enabling them to reallocate resources to keep the overall project on track. Additionally, preplanning construction logistics significantly lowered fuel use and associated greenhouse gas emissions and reduced construction noise for those living and working in the vicinity. The project was finished in 93 days, keeping traffic disruption to a minimum during development and ensuring unimpeded travel for trains and vehicles.

IMAGES COURTESY OF LAING O'ROURKE

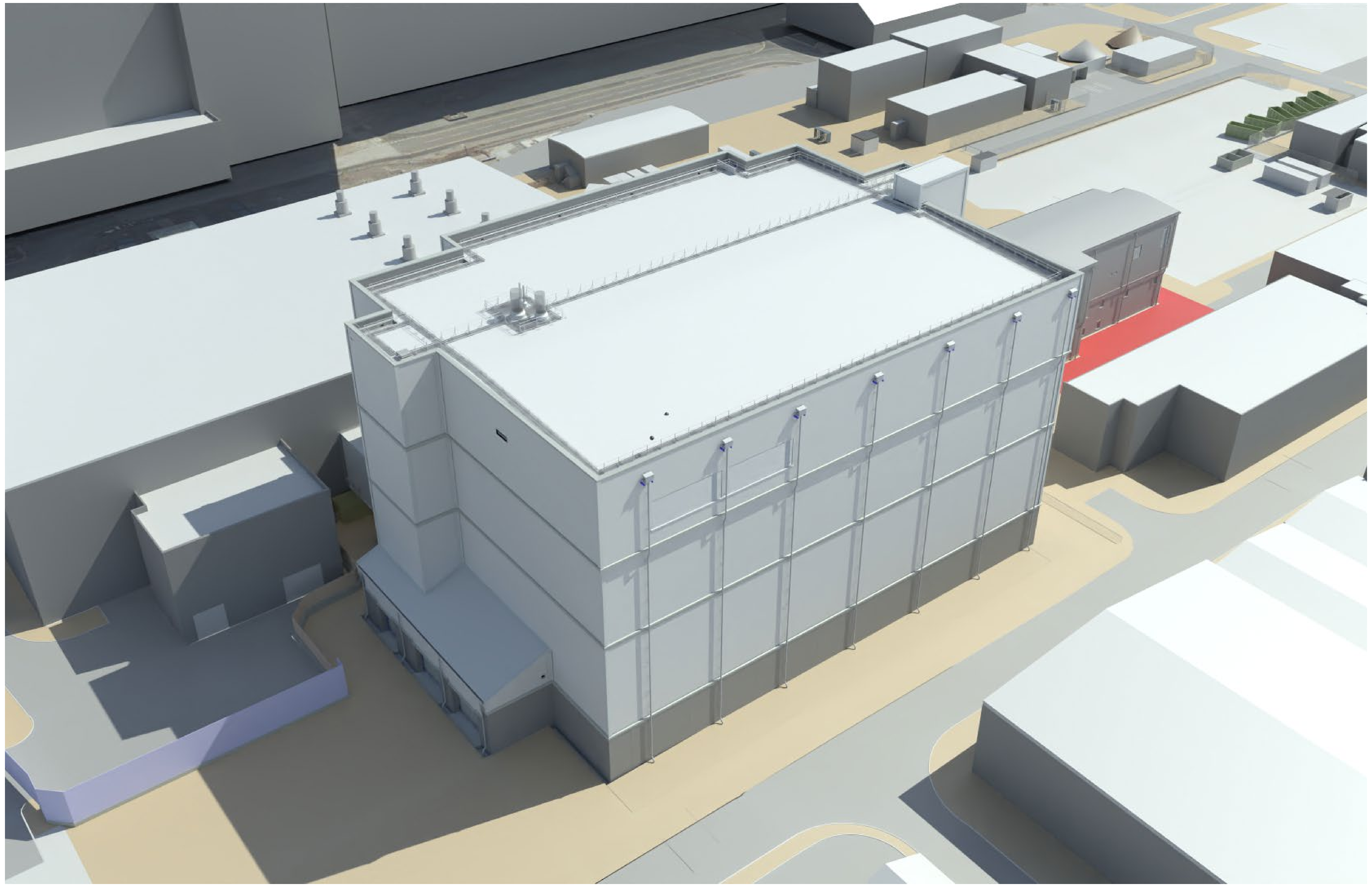
The level crossing removal project team developed construction staging plans more than 70% faster.

IMAGES COURTESY OF LAING O'ROURKE

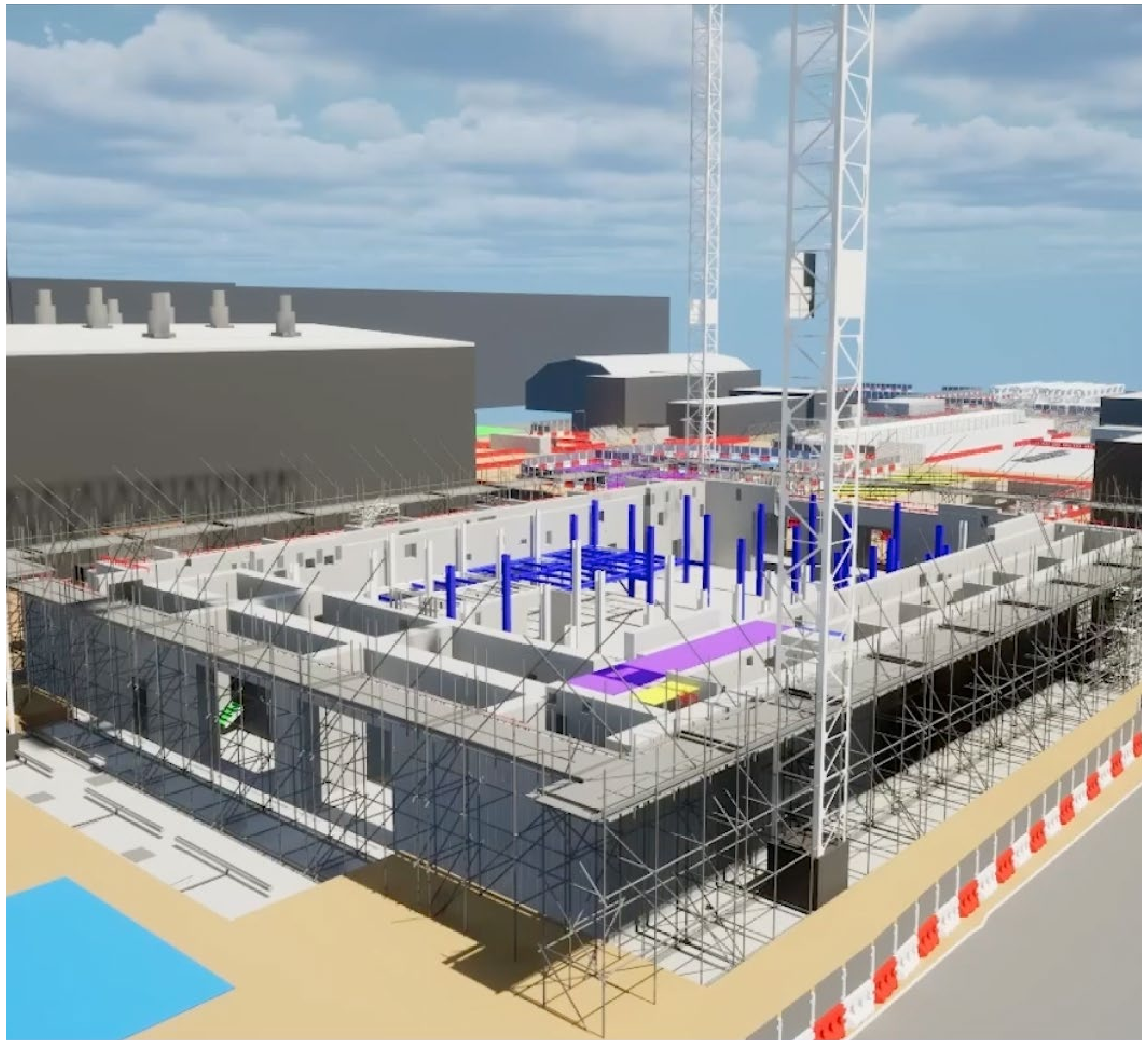
Case study

Accessing high-quality engineering data in the field

The Sellafield Retreatment Plant



IMAGES COURTESY OF PROICERE DIGITAL



The United Kingdom's Nuclear Decommissioning Authority is responsible for cleaning up and decommissioning the country's earliest nuclear sites, including safely transferring approximately 140 tons of civil separated plutonium into more modern facilities. One of these facilities is the Sellafield Retreatment Plant, which will repackage and retreat plutonium packages. The plant is designed to operate safely for the next 60 to 100 years.

Constructing a facility to process plutonium safely into the next century involves unique complexities (for example, on-site personnel need clear and easy-to-understand escape routes) and requires specialized tools tailored to nuclear decommissioning and waste management. Proicere Digital established a digital twin to enable project teams—both in the office and in the field—to visualize, plan, and execute the complex site work with greater control and transparency.

Using the digital twin, the team could conduct digital rehearsals to, for example, pinpoint crane collapse zones and fire escape routing, enabling engineers to determine the safest and fastest escape route on any day for workers on-site. One simulation revealed that three of four planned escape routes would be blocked during an upcoming wall pour, prompting an early redesign of scaffolding months ahead of schedule.

Centralizing project intelligence within the digital twin enabled teams in the field, operating 150 miles from the main office, to share updates in real time. The project team identified and mitigated more than 160 risks, avoided over 500 days of rework, and saved an estimated GBP 80 million in schedule-related benefits on a project valued at GBP 1.3 billion.

IMAGES COURTESY OF PROICERE DIGITAL

The Sellafield Retreatment Plant project team saved an estimated GBP 80 million in schedule-related benefits.

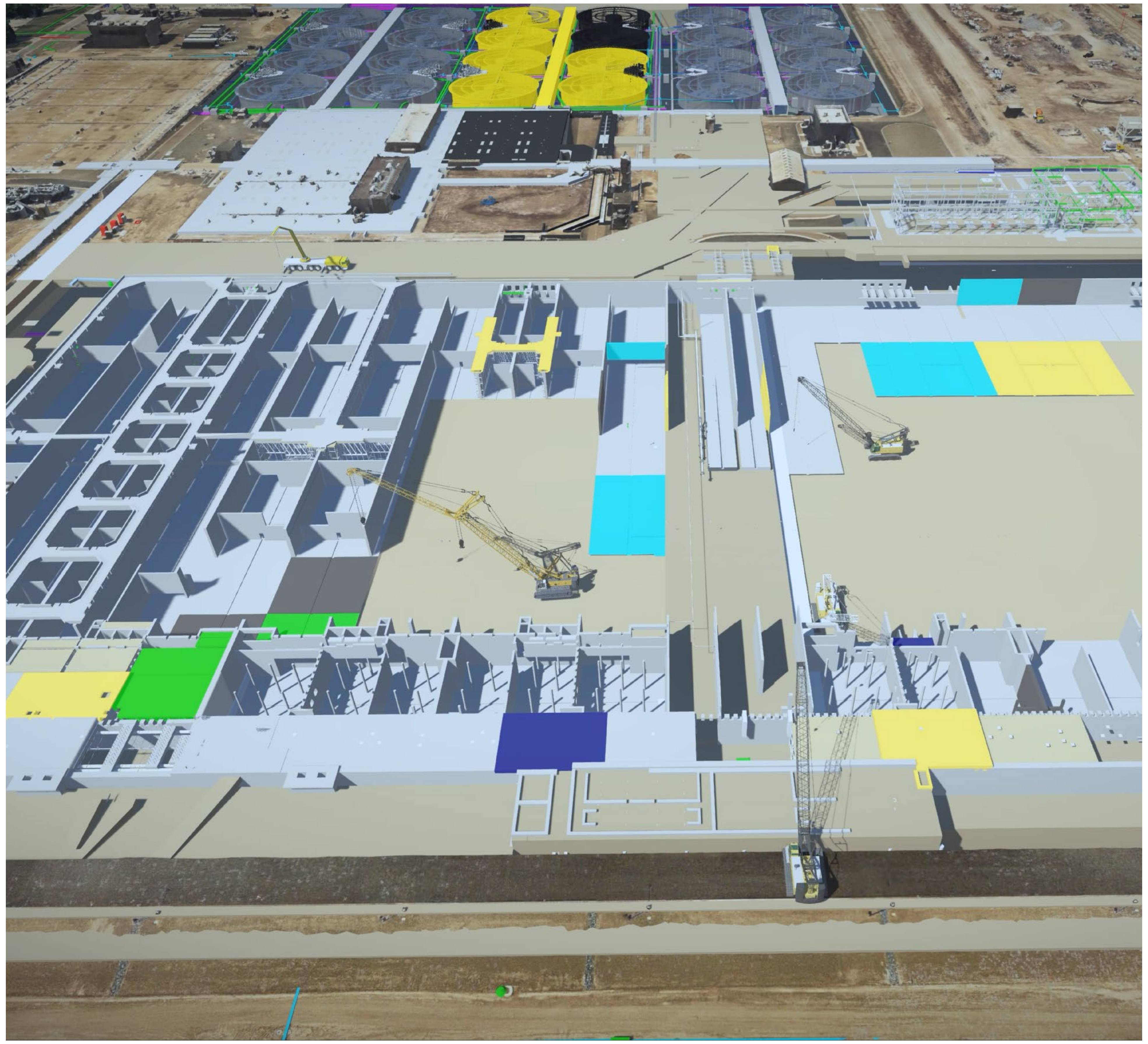
IMAGES COURTESY OF PROICERE DIGITAL

Case study

Tracking and optimizing complex resources

The EchoWater Project

IMAGES COURTESY OF PROJECT CONTROL CUBED LLC.



Tracking and optimizing complex resources across 22 projects—many occurring simultaneously—on an active wastewater treatment facility is a tall order. For the Sacramento Area Sewer District, the EchoWater Project represented not only one of the largest public-works programs in the region's history but also one of its most complex—spanning over 100,000 construction activities and involving dozens of stakeholders across a decade.

To manage the complexity and scale, digital construction planning specialist Project Controls Cubed built a federated digital twin that brought together design models, construction schedules, and cost data into a single, continuously updated environment.[7] The digital twin served as the foundation for planning, coordination, and decision-making, providing real-time visibility into progress, resource allocation, and complex construction sequences across multiple projects.

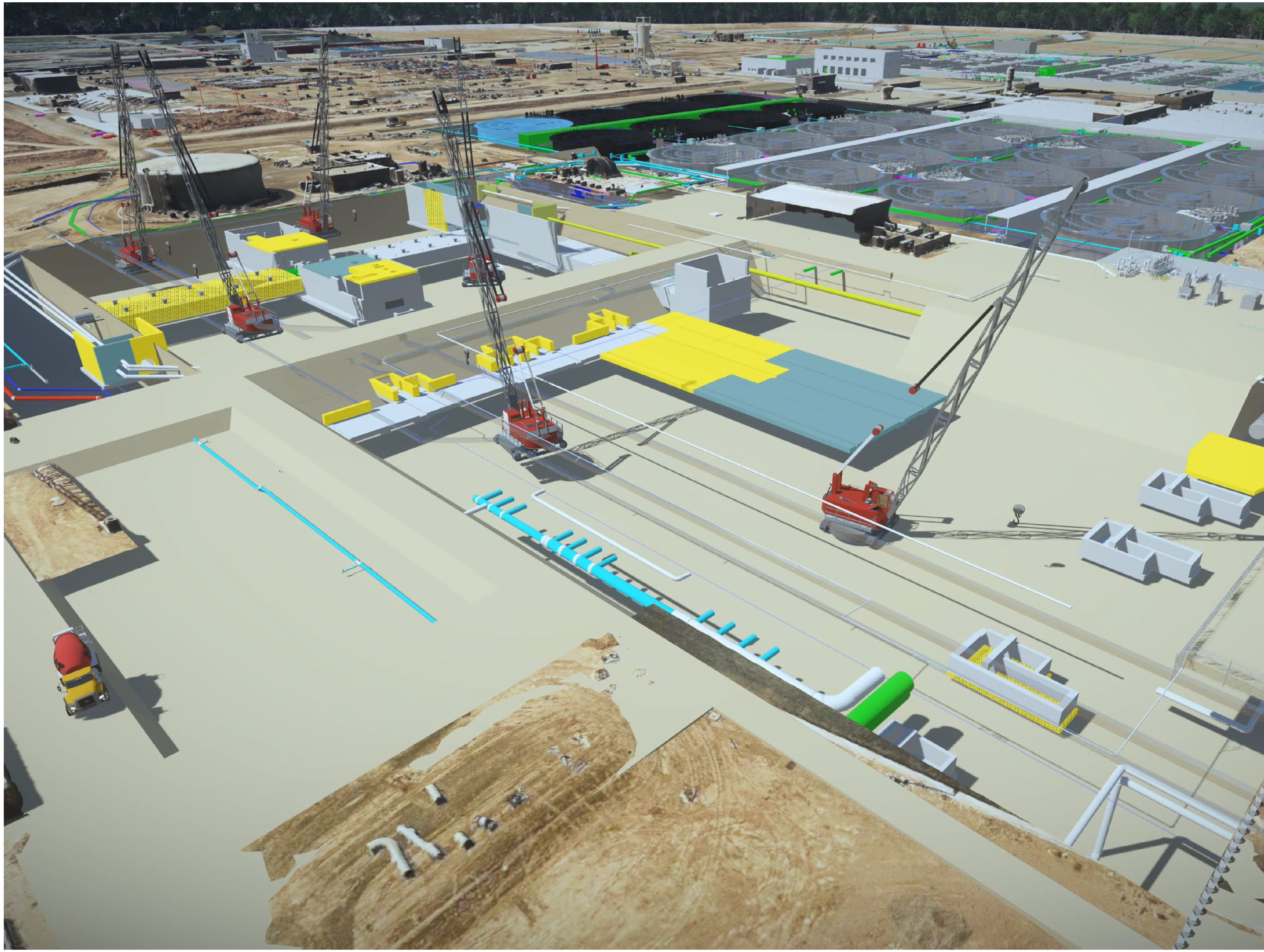
Stakeholders used the digital twin to rehearse shutdowns, assess access constraints, and identify schedule risks in advance, which helped them avoid costly conflicts and enabled smooth execution across interconnected projects. With multiple projects unfolding in parallel, they were able to develop a detailed digital program schedule linked with resource and cost information that could be monitored in real time, tracking and reporting progress and financial status.

The use of the digital twin throughout the project allowed the team to shift from reactive problem-solving to proactive planning. As a result, the entire program was delivered on time and USD 400 million under budget. Savings are now being reinvested in agricultural water reuse efforts expected to benefit up to 16,000 acres of farmland.

7 Neda Simeonova, "EchoWater Project Helps Relieve Multiyear Drought in Sacramento," *Water Finance & Management*, June 17, 2024, https://waterfm.com/echowater-project-helps-relieve-multiyear-drought-in-sacramento/.

IMAGES COURTESY OF PROJECT CONTROL CUBED LLC.

The entire EchoWater Project was delivered on time and USD 400 million under budget.



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From debut to decommissioning

Optimizing operations while reducing costs

A significant share of infrastructure lifecycle costs occur during operations. As assets age, populations grow, and climate-related events become more frequent and severe, the risks of service disruptions, safety incidents, and escalating maintenance and insurance costs also increase.

Yet the information needed to mitigate those risks—engineering design files, construction models, asset records, sensor data, maintenance logs, and inspection reports—is often spread across disconnected systems and incompatible formats.

Digital twins address this by unifying asset information into a single comprehensive and federated view. With a clearer view of structural design tolerances, material specifications, condition-monitoring data, and component histories, owner-operators can better prioritize maintenance and replacement efforts. And when conditions shift suddenly, digital twins can respond by visualizing anomalies—such as rising pressure, shifting vibrations, or abnormal wear patterns—and provide early warning to teams, helping them avoid costly downtime and disruptions.

That same unified view can also help owner-operators improve field safety and the operational sustainability of existing assets. By layering data from IoT devices and high-fidelity 3D models from drone imagery, teams can monitor asset conditions remotely, reducing the need for on-site inspections by in-demand experts and limiting crew exposure to hazardous environments. In addition to supporting day-to-day operations, digital twins can help demonstrate the safety and sustainability of existing assets—providing owner-operators and asset investors various benefits, such as more favorable insurance terms.

Consider the following examples.

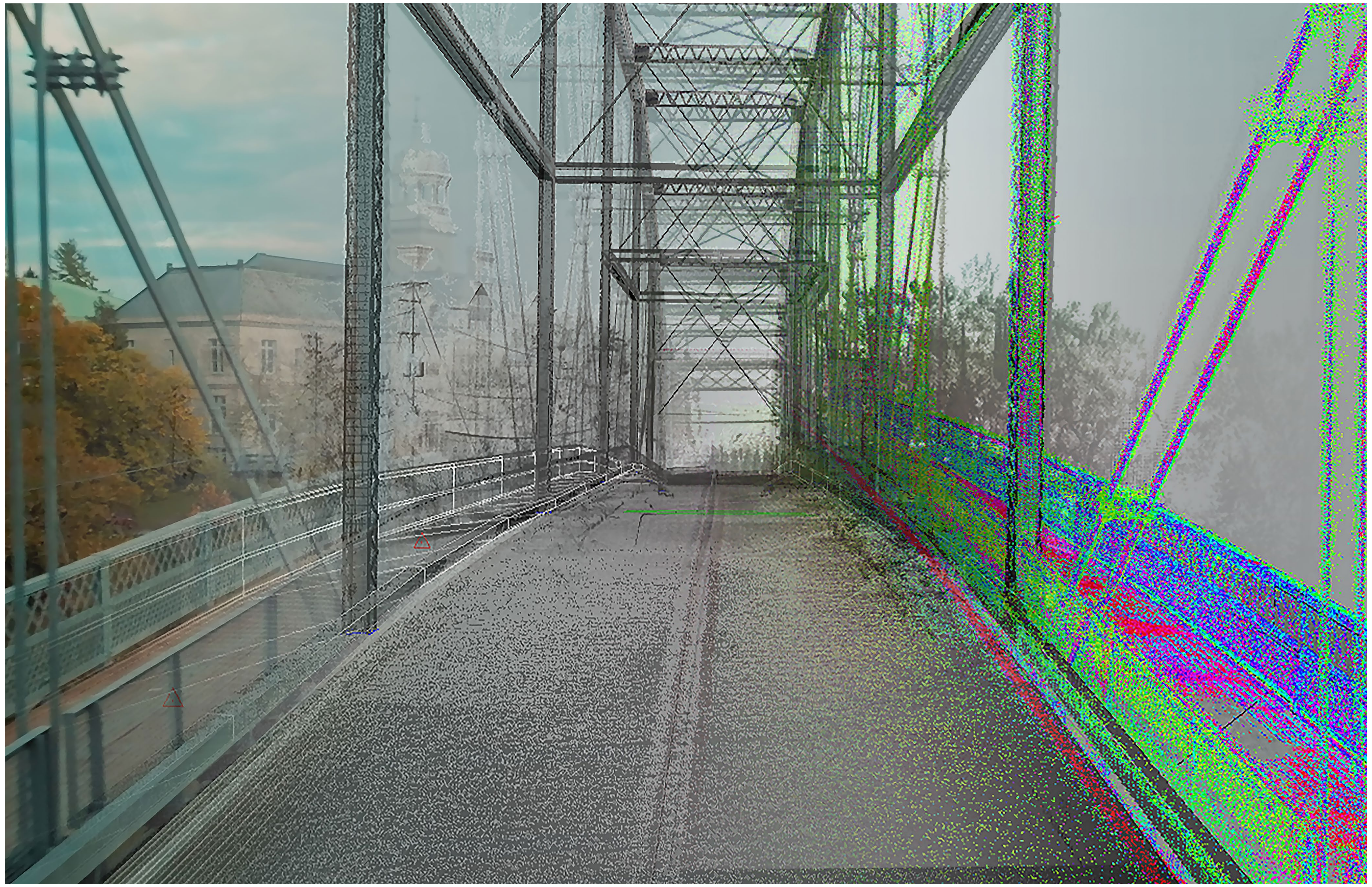
Common operations phase challenges

- Minimizing disruptions when breakdowns occur
- Responding quickly to potential operational disruptions
- Maintaining safety and sustainable operations
- Planning and scheduling maintenance with incomplete or inaccurate data

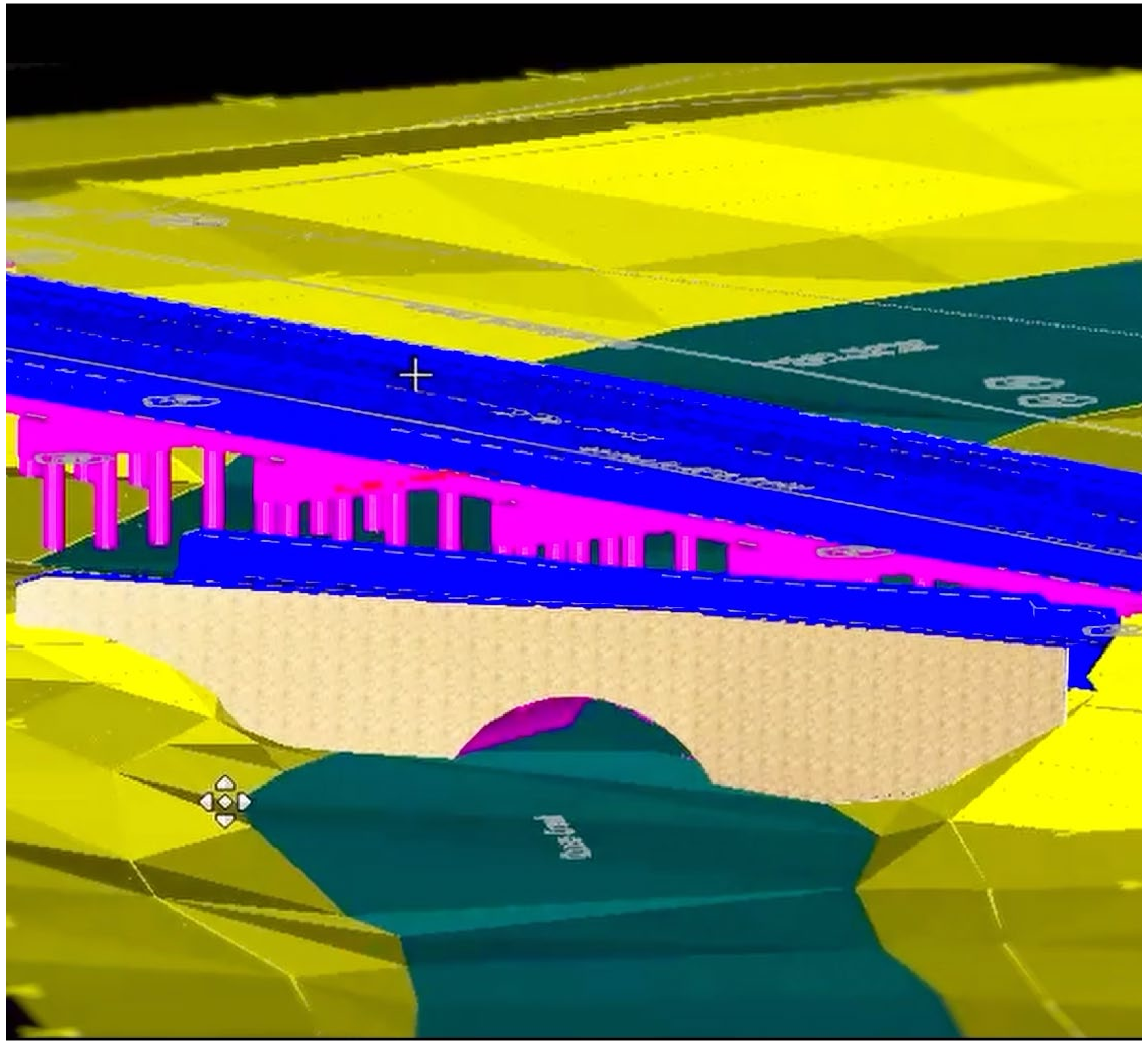
Case study

Minimizing disruptions when breakdowns occur

The Bridging Kentucky Program



IMAGES COURTESY OF QK4, INC.

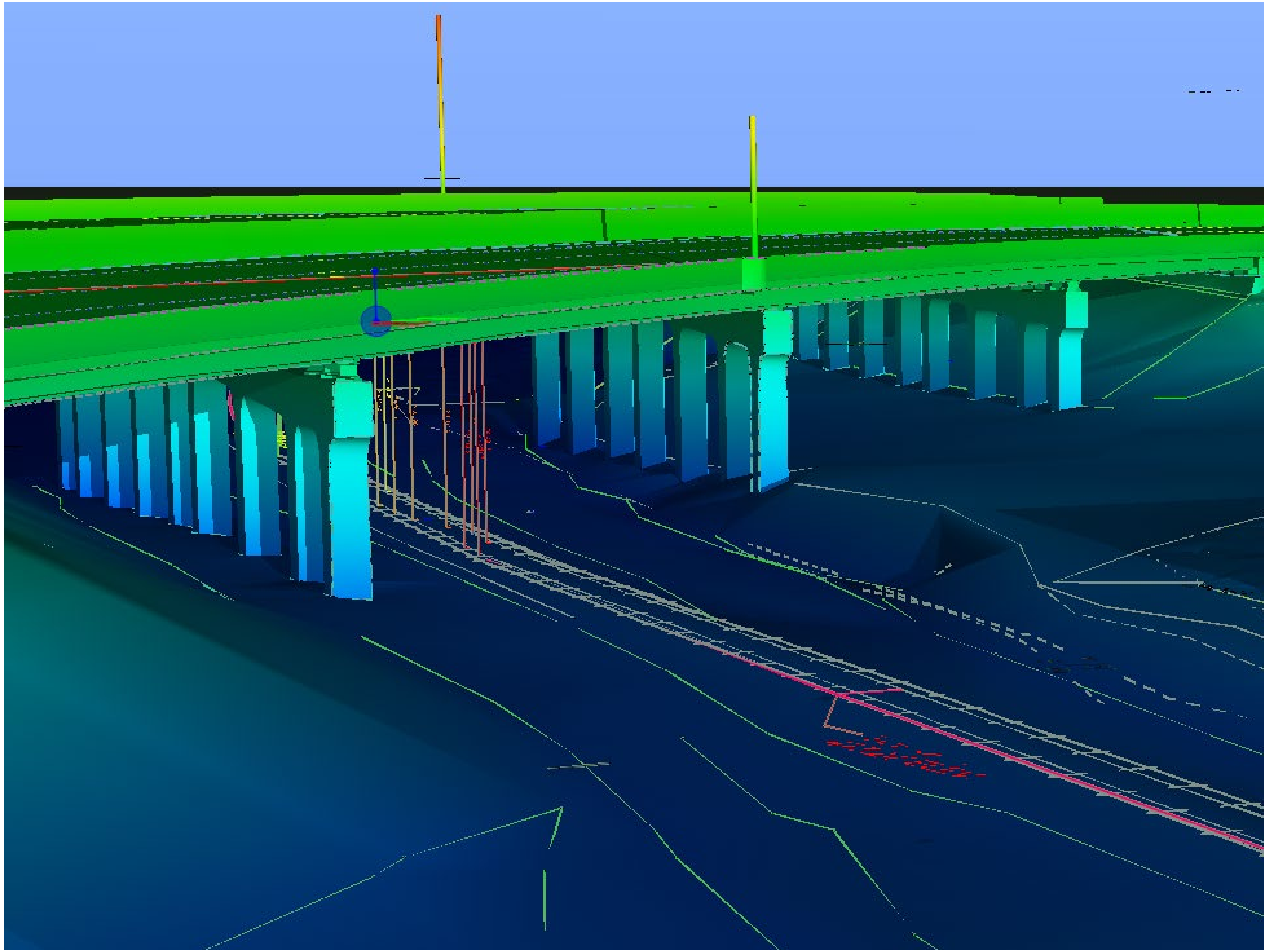


IMAGES COURTESY OF QK4, INC.

Service disruptions caused by asset failures can be costly, pose safety risks, and threaten to disrupt commerce, emergency response, and daily commutes. In Kentucky, where more than 1,000 bridges have been identified as damaged or degraded, the Kentucky Transportation Cabinet (KYTC) launched an ambitious program to inspect, rehabilitate, or replace deficient structures in just six years. The volume of this project alone would have constituted a major challenge, but the difficulty was doubled by the accelerated timeline.

To reduce bridge survey time and accelerate critical infrastructure repairs, civil engineering firm Qk4 replaced conventional approaches with a digital twin. The team combined drone imagery, 3D laser scanning, and geospatial data—including survey control, underground utility information, and right-of-way locations—into comprehensive virtual representations of each bridge. This federated data became a critical asset for engineers planning repairs by enabling faster, more informed decisions about prioritization and design.

What once took 182 hours per bridge was reduced by more than 50%, allowing Qk4 to survey 50 bridges in a month—more than the previous annual output. Survey costs dropped by over USD 10,000 per bridge, saving the state USD 3.5 million in survey work alone. Most important, the program was delivered for USD 320 million, less than half of the initial projected cost, enabling urgent repairs across rural and urban communities far ahead of schedule.



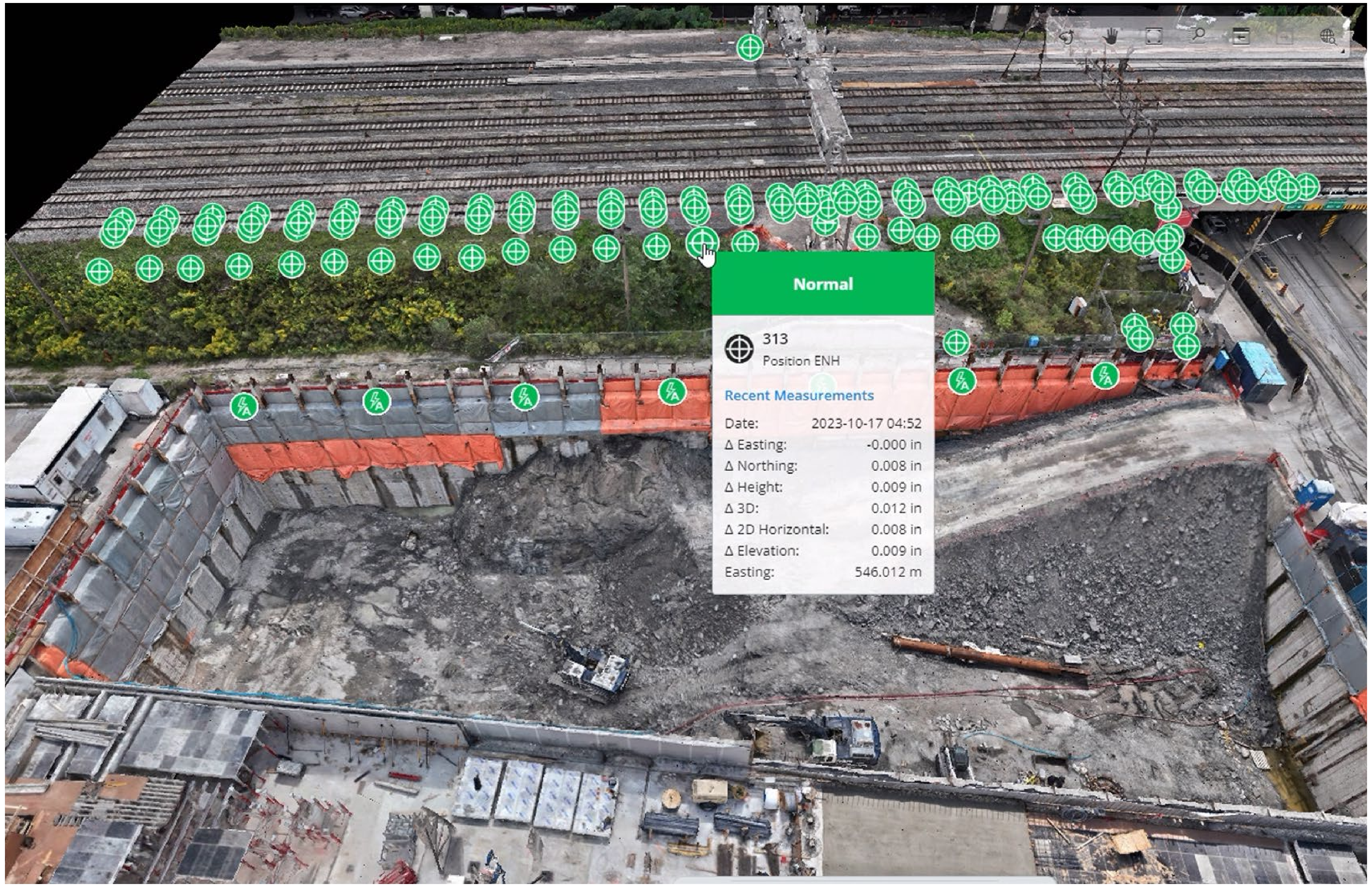
The Bridging Kentucky Program was delivered at less than half of the initial projected costs.

IMAGES COURTESY OF QK4, INC.

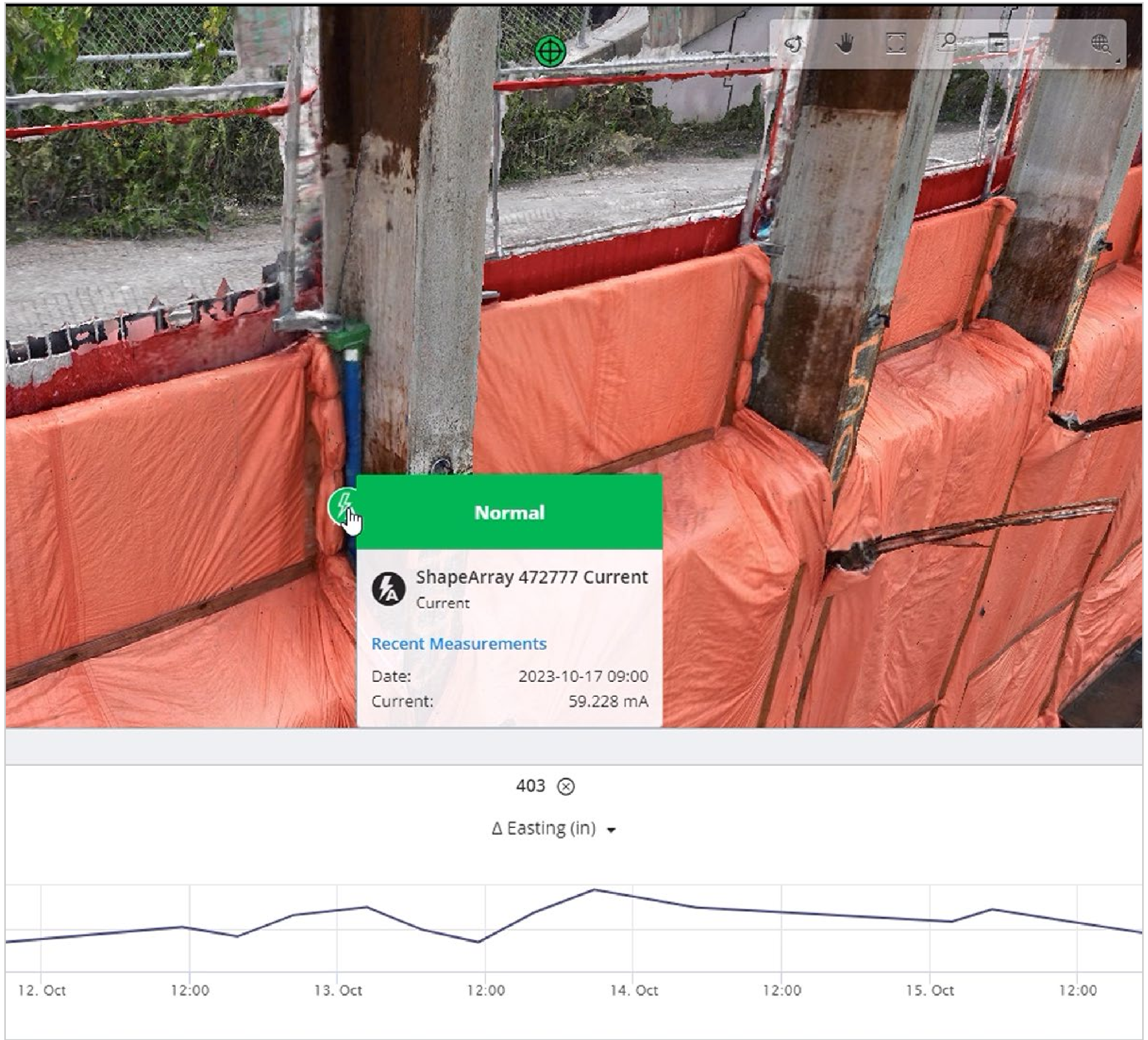
Case study

Responding quickly to potential operational disruptions

Toronto's 31 Parliament Street Project



IMAGES COURTESY OF MONIR PRECISION MONITORING



IMAGES COURTESY OF MONIR PRECISION MONITORING

Managing infrastructure operations often means accounting for adjacent activities that could affect critical assets. This was especially true in Toronto's historic Distillery District when a 41-story luxury condominium development—31 Parliament Street—was being built alongside the Union Station Rail Corridor (USRC). Supporting more than 300,000 daily commuters, the transit corridor is one of Canada's busiest, which made uninterrupted rail service during excavation and construction of 31 Parliament Street a top priority.

To meet the strict guidelines for work in and around the corridor, Monir Precision Monitoring was contracted to track conditions at the excavation site and the USRC railway, helping to protect the corridor from displacement, avoid service disruptions, and enable rapid response before operations were affected.

At the heart of Monir's approach was a digital twin that holistically visualized the project site and railway corridor, providing real-time insights that could assist with proactive decisions. It combined inputs from a range of sensor instruments with reality modeling, borehole data, and 3D engineering models to visualize instrumentation data in the full context of current and historical site conditions and against geotechnical plans.

Using the digital twin, project managers could view custom dashboards displaying site health. Engineers received immediate alerts if thresholds were exceeded, enabling them to implement preemptive measures quickly and respond to client needs. Stakeholders could toggle between live sensor data, drone imagery, and construction models to see how excavation was progressing.

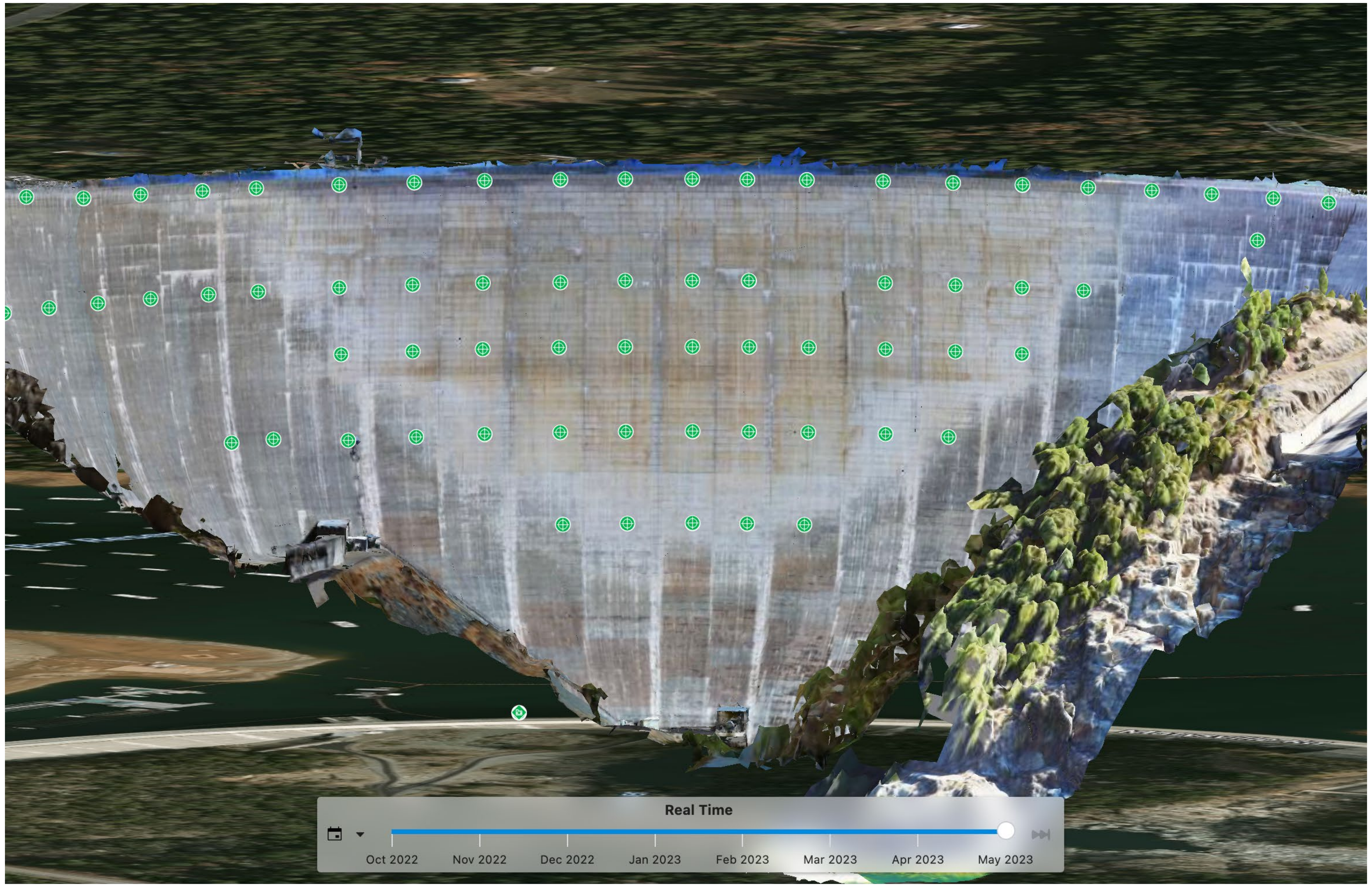
By detecting and responding to issues early, the project team ensured that rail service ran uninterrupted during excavation. This approach also increased site monitoring efficiency by 40 percent and saved over 3,000 hours in on-site assessments and more than USD 1 million in monitoring costs.

The 31 Parliament Street construction kept nearby rail service running during excavation and increased site monitoring efficiency by 40%.

Case study

Maintaining safety and sustainable operations

New Bullards Bar Dam



IMAGES COURTESY OF YUBA WATER AGENCY

Owned and operated by Yuba Water Agency, New Bullards Bar Dam is a 645-foot-tall concrete arch dam—California's second tallest and the fifth tallest in the United States. Built in 1970, the dam reduces flood risk, generates clean hydropower, and ensures a reliable water supply for county residents, the area's agricultural community, and the surrounding environment.

The dam's legacy monitoring system required time-consuming, costly, and hazardous manual data collection that enabled analysis of only a portion of the dam. To maintain safety and sustainable operations, Yuba Water launched a project to modernize the system and give staff a more accurate and complete view of the dam's performance—particularly during severe weather events and seismic activity.

Using a digital twin, the team can now visualize and track structural movement over time as the dam is exposed to environmental stress. For example, during heavy rainfall or following an earthquake, engineers can quickly assess structural conditions and analyze deformation data directly within the digital twin—eliminating the need to switch among multiple software platforms. Automated alerts, triggered by predefined thresholds, give teams timely notice when conditions warrant closer inspection.

Today, the system collects data twice daily from more than 80 sensors monitoring water levels, temperature shifts, and hydrological and seismic activity. According to Yuba Water, the system delivers 1,000 times more data points per week than the manual process did—accelerating issue detection and enhancing risk assessment and dam safety.

IMAGES COURTESY OF YUBA WATER AGENCY

Yuba Water Agency gained 1,000 times more weekly data monitoring points, accelerating issue detection and enhancing safety.

IMAGES COURTESY OF YUBA WATER AGENCY

What's next: Expanding the capabilities of digital twins

Imagine that a design team needs to evaluate the location for a new project. The team uses an AI-powered digital twin of the site location to test a series of "what if" scenarios—factoring in 3D geospatial data, geotechnical data, and decades of historical weather and environmental data, as well as engineering design models of the new asset and those of existing adjacent infrastructure.

What if we experience a 100-year flood—or a flood followed by an earthquake? What if we choose different materials? What if we shift the highway alignment to avoid underground utilities? Using natural language, the team can evaluate key environmental constraints—including flood zones, underground utilities, and slope stability—that may affect design decisions.

Instead of exporting files into external design tools, the work happens natively within the digital twin. Designers can generate models, drawings, and other deliverables directly from the twin, accelerating design iteration and enhancing collaboration.

When the design is approved, the twin seamlessly transitions to the construction team. Simulations powered by game engines provide high-fidelity, interactive visualizations of the construction site to give city officials and residents a clear understanding of site conditions, staging plans, and safety measures—making complex information easier to comprehend and decisions easier to make. Field crews use augmented reality to visualize subsurface conditions—utility lines, conduits, and soil composition—before excavation begins.

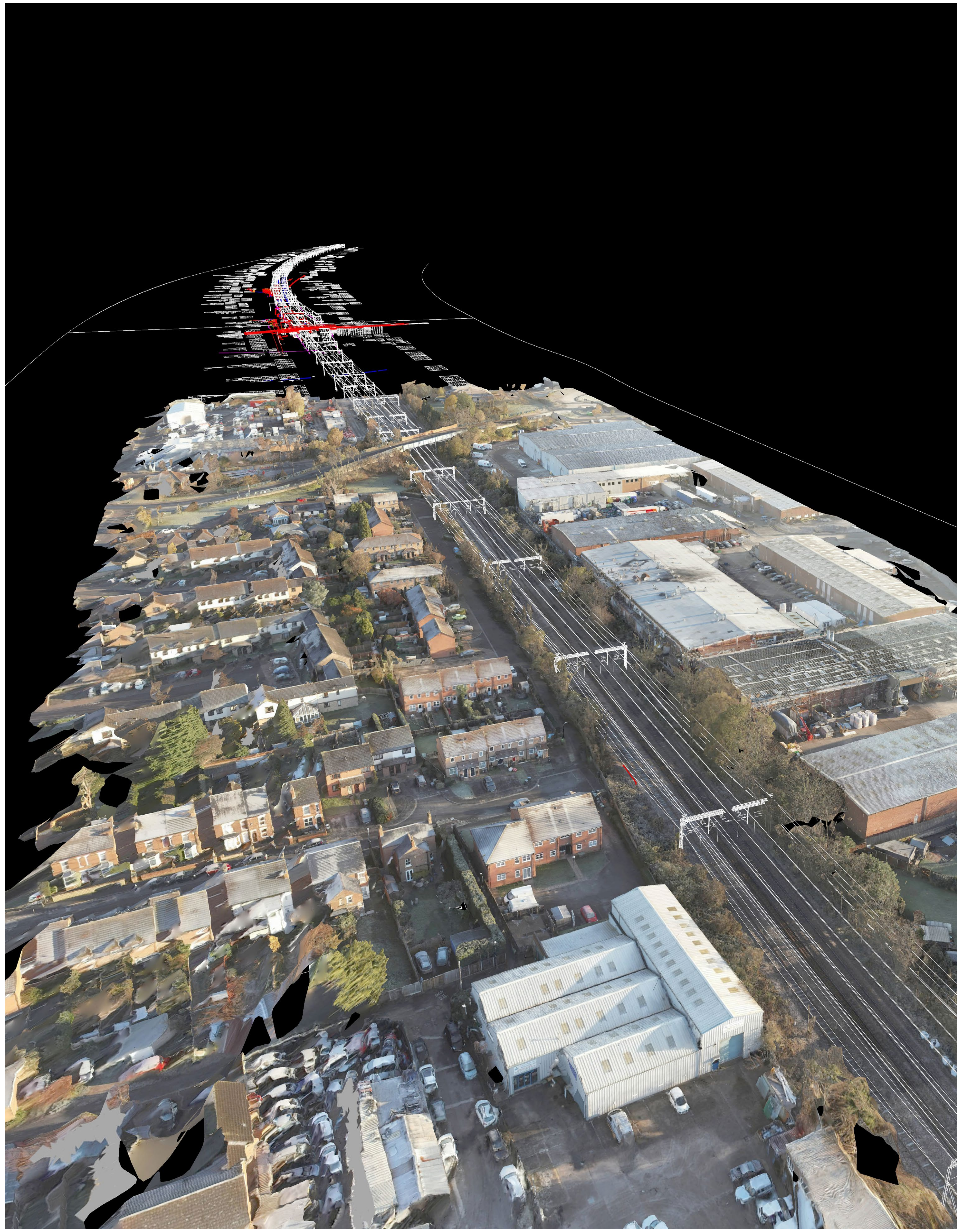
Once built, the digital twin continues into operations—no re-creating data, no starting over. Operations teams use the twin to conduct virtual inspections, view live sensor data, and simulate asset performance under future stress conditions. If a sensor detects a pressure anomaly in a buried pipe, operators immediately see the pipe in its 3D geospatial context and can respond within seconds.

This isn't speculative. What's next is not a matter of technology innovation but a matter of integrating existing advanced technologies within and across teams, and at large scale—for instance, creating a digital twin of an entire road network across a city or state. And early adopters are already reaping the benefits of these capabilities.

Enhanced visualization tools—including augmented reality (AR), virtual reality (VR), and browser-based 3D tiles that overlay geotechnical data, infrastructure details, and other geospatial context—are already improving how infrastructure professionals engage with the natural and built environment. What used to require travel and guesswork can now be more precisely simulated and validated virtually.

AI-powered digital twins integrated with the large language models underlying generative AI will reshape access to information and our ability to understand how assets are performing. Project managers can ask natural-language questions, either by inputting queries or by simply talking to the digital twin, and receive answers based on the twin's historical, spatial, structural, and operational data.

The interoperability of digital twins across the lifecycle ensures that valuable data remains intact and additive as the asset transitions from one phase to another. Design choices inform construction logic. Construction updates and as-built data flow into asset operations and maintenance. Every action helps squeeze out costs—both immediate and long term—while also extending the asset's lifespan and optimizing its performance.



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Getting started: Building the foundation for success

Traditional infrastructure workflows are built around file- and document-based processes—and those won't disappear overnight. A well-designed digital twin evolves alongside traditional systems, augmenting them rather than attempting to replace them wholesale.

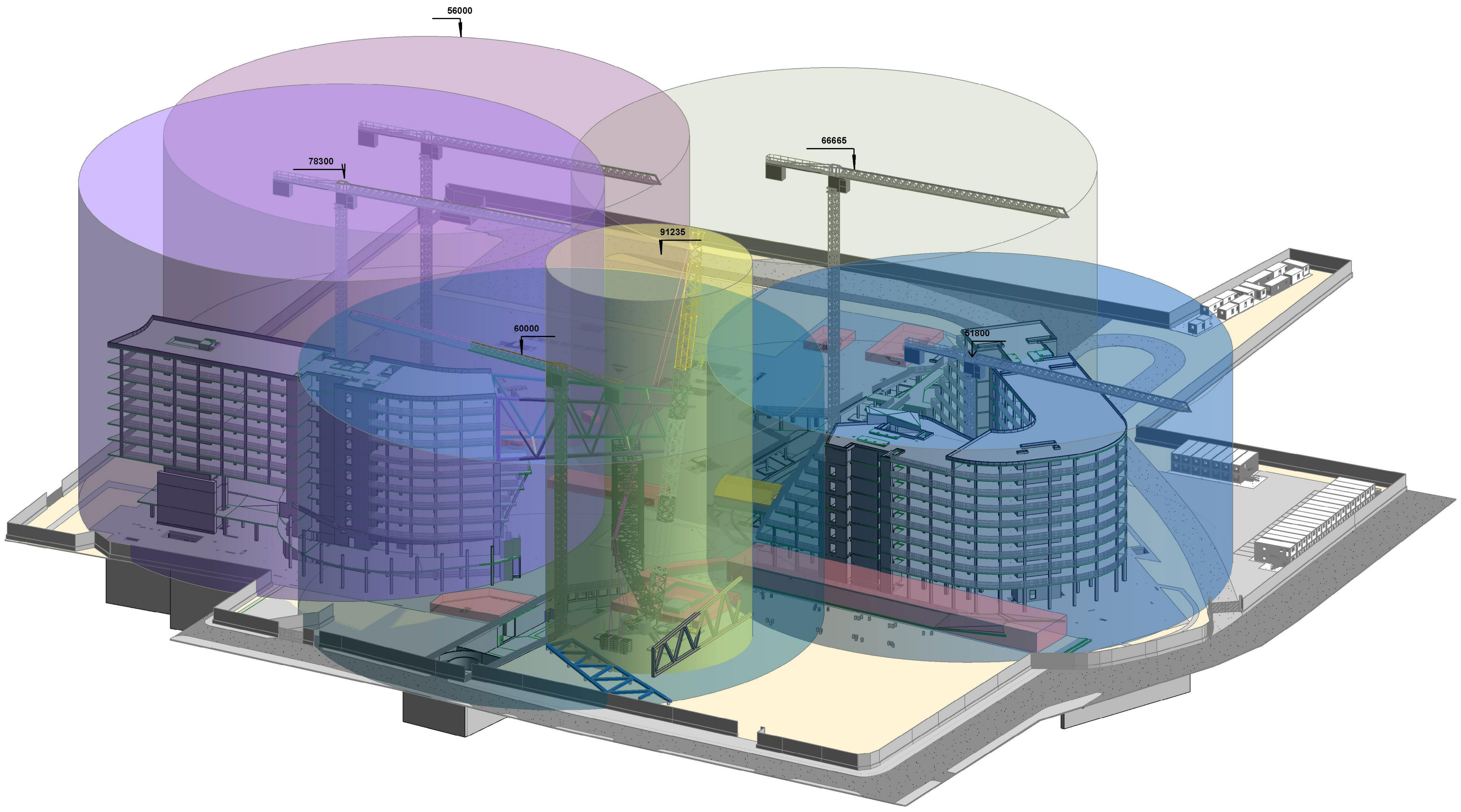
Where to start? We find that three steps can put organizations on the right track for success:

- **Start with a clear use case.** Rather than unifying all data sources at once, begin with a focused use case that delivers measurable value, such as reducing inspection costs or improving asset visibility. For example, an owner-operator might start by digitizing paper design drawings (and extracting the piping and instrumentation diagram design data) and incorporating them with maintenance records, inspection histories, and related documentation into a digital twin to enable team members to locate asset information faster. As efficiencies grow, the twin can expand—integrating 3D geospatial imagery, sensor data, or photogrammetry to enhance predictive maintenance, safety, and sustainability. The key is solving a real problem, demonstrating value, and scaling from there.
- **Match the data frequency to the use case.** Real-time data isn't always necessary. How often an organization updates its digital twin depends on the use case. A construction-phase twin may need only daily or weekly updates to track progress and materials, while a dam monitoring system might demand real-time, continuous data. Avoid over-engineering data feeds up front. Instead, match the frequency to the decision cycles you're trying to support.
- **Prioritize open, interoperable platforms.** A sustainable digital-twin strategy isn't just about what the platform can do today—it's about how easily people can use it and build on it over time. That starts with designing digital twins for openness and extensibility, including the use of open-source components and open standards and APIs. Open-source components allow new capabilities and data sources to be easily added as needs evolve. Open standards and APIs democratize access to asset data, ensuring that authorized users can read, understand, contribute, and leverage data when needed rather than locking it inside a proprietary system.

Conclusion

As the examples throughout this paper show, digital twins provide a proven advantage in solving infrastructure challenges at every stage of the asset lifecycle. By unifying and visualizing data from across systems—geospatial context, engineering models, construction scheduling, operational records, and more—digital twins create a dynamic view of infrastructure for faster and better-informed decision-making.

Even with limited data, organizations can get started, laying the foundation for more advanced use cases over time. Complex, siloed processes become more connected, collaborative, and efficient. And as digital twins are integrated across the infrastructure lifecycle and combined with other advanced technologies, their value only grows. Enhanced visualization capabilities using geospatial and game engine technology, AI-powered insights, and AR/VR capabilities help teams not only gain better situational awareness but also plan for the future and act with confidence.



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Corporate Headquarters
685 Stockton Drive, Exton, PA 19341, United States
1-800-BENTLEY (1-800-236-8539)
Outside the United States +1 610-458-5000

Bentley EMEA
6th Floor, 1 Cumberland Place, Fenian St.
Dublin 2, D02 AX07, Ireland +353 1 436 4600

Bentley Asia
Bentley Systems (Beijing) Co., Ltd.
Units 01A-06, 19th Floor, Tower 2
China Central Place, No.79
Jianguo Road, Chaoyang District
Beijing 100025, China
+86 10 52258350
+86 10 59297110

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