Digital Delivery for a Safe, Durable, and Reliable Future

By Meg Davis, industry marketing director for roads and bridges, Bentley Systems

Transportation agencies around the world face numerous challenges in how to best plan, design, construct, and operate safe, resilient, and sustainable infrastructure. Aging infrastructure, growing populations, and increased traffic and congestion all put pressure on owners and contractors of roads, bridges, and associated structures to identify and utilize cost-effective and efficient ways to do their jobs. They must minimize the impact of transportation projects on the environment and reduce their carbon footprint. In addition, with an aging workforce and high employee turnover, the need to adopt digital tools, techniques, strategies, and methodologies to streamline processes and enable collaboration across the supply chain is ever-present.

Investment in Infrastructure Is Long Overdue

The world's roads and bridges are critical for moving an ever-increasing number of people and goods. Recent years have seen an increasing number of incidents related to aging infrastructure. Infrastructure failures—such as the bridge in Genoa Italy, the Interstate 35 Mississippi River bridge collapse, and the Interstate 5 Skagit River bridge failure in the state of Washington—demonstrate the importance not only of good quality design and construction, but also of proper operations and maintenance of infrastructure assets.

In many countries, a large number of infrastructure assets have been in place for over 40 years. In the United States, almost 8% of bridges are considered structurally deficient, and wear and tear on roads has left 43% of our public roadways in poor or mediocre condition. A recent study in the U.K. found that over 2,000 bridges were not suitable to carry the heaviest vehicles permitted on the public highway. But it is not just the wear and tear that affects the stability of older infrastructure assets for modern demands. Changing needs have placed new stresses on infrastructure that may not have been considered when they were first designed and built. Asset deterioration increases with heavier vehicles, increased traffic volumes and higher speeds. Roads and bridges designed for traffic 40 years ago are now coping with very different loads, which can contribute to infrastructure failure. In addition, some infrastructure assets were built to comply with less stringent safety standards than we have in place today. Bringing those assets up to date carries inherent risks both during routine maintenance and upgrades, and during the remaining life of the asset.

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Image Caption: U.S. Infrastructure Report Card for Roads. *Image courtesy of ASCE.*

Climate Change and Sustainability

Climate change presents a significant and growing risk to our transportation infrastructure, the communities it serves, and the people who rely on it. Rising temperatures, fires, droughts, flooding, and severe weather that are worsened by climate change put stress on transportation infrastructure. In recent years, we have seen numerous examples of climate change. In the U.S., we have experienced floods in Michigan, wildfires in California, mudslides in Colorado that followed a year of extreme wildfires, and the recent Hurricane Ian in Florida. In 2022, Europe faced a record-breaking heatwave and wildfires across the Mediterranean.

Climate variability and change pose threats to transportation systems, and the impacts may include flooding and damage to highways and tunnels and weakened structures, such as bridges. Severe conditions may reduce the life of capital assets, increase operational disruptions, and create the need for new infrastructure such as evacuation routes. Interruptions to emergency routes or infrastructure failure can make travel conditions unsafe. They jeopardize not only transportation infrastructure, but they can weaken mobility and the economy, and compromise the safety of the traveling public. It requires us to examine the design, construction, siting, and maintenance of infrastructure and make necessary changes to how we design and construct these assets, allowing our transportation infrastructure to be built resilient to climate change.

Infrastructure Investment and Workforce Challenges

In addition to the Infrastructure Investment and Jobs Act (IIJA) in the U.S., which was established to provide funding mechanisms to enable state DOTs and their partners to invest in roads and bridges, there is also infrastructure investment taking place in Europe and Asia. IIJA includes a new USD 100 million grant program that encourages state departments of transportation to accelerate their usage and deployment of Advanced Digital Construction

Management Systems (ADCMS). These systems are proven digital technologies and processes that manage construction and engineering activities, including commercial cloud-based advanced decision-support technologies for infrastructure planning and coordination, commercial building information modeling, and digital 3D design software.

This new grant money, included in the Federal Highway Administration's (FHWA) Technology and Innovation Deployment Program, allows states to purchase technology platforms and develop best practices. It also helps them develop guidance to assist with updating regulations, allowing project sponsors and contractors to fully capture the efficiencies and benefits of advanced digital construction management systems, among other uses. As digital transformation in the construction and engineering sectors is a priority for the U.S. Department of Transportation (USDOT) and the FHWA, this program is a good way for states to take advantage of this momentum.

But obtaining funding is just the first step in the construction, rehabilitation, and maintenance of our road and bridge infrastructure. Once that funding becomes available, infrastructure owners and their partners may face staffing challenges as they plan and design infrastructure projects. In addition to a competitive job market for engineers, the retirement of experienced personnel, sometimes called the "silver tsunami," could leave owners and their supply chain without experienced engineers and the knowledge base needed to expeditiously produce project designs and get them out to bid. It will be important to proactively shape the future transportation workforce, providing resources to fill skills gaps, recruiting future workers, and providing the tools and technology to get the work done.

Making Transportation Networks Safer and More Efficient

Transportation planning and roadway design have traditionally focused on the needs of drivers rather than those of all users of the street. After World War II, many communities were designed to facilitate easy and fast access to destinations using automobiles. Over time, this approach contributed to the development of an environment where other modes of transportation—including walking, bicycling, or transit—did not see the same level of investment.

Complete Streets—also known as Living Streets, Home Streets, or Woonerf outside of the U.S.—is a street that is designed and operated to enable safe use and support mobility with all users in mind to make the transportation network safer and more efficient. Complete Streets can address a wide range of elements, such as ADA-compliant sidewalks and crossings, bicycle lanes, bus lanes, median islands, roundabouts, accessible pedestrian signals, curb extensions, streetscapes, and landscape treatments. This approach can reduce motor vehicle-related crashes, as well as pedestrian and bicyclist risks. It promotes walking and bicycling by providing safer places to achieve physical activity and can increase business traffic in local communities.

A Complete Streets policy ensures that transportation planners and engineers consistently plan, design, operate, and maintain the entire roadway and roadway networks with all users in mind, including bicyclists, public transportation vehicles and riders, and pedestrians of all ages and abilities to maximize transportation choices. The benefits of implementing a Complete Streets philosophy are tangible. In the U.S., the FHWA found that increasing lighting at intersections was found to have reduced nighttime injury crashes involving pedestrians by as much as 42%. Adding a bicycle lane can reduce the total number of crashes by as much as 49%, and changing a two-way intersection with stop signs to a roundabout can reduce fatal crashes by 82%.

Digital technologies are helping drive innovation for initiatives, such as Complete Streets. Over the past few years, there has been a major shift from 2D plans to digital delivery and 3D design, which has helped engineers communicate information about the project scope to stakeholders and the community. Before this technology, engineering consulting firms would schedule public hearings or town hall meetings to show a set of 2D drawings that typically only an engineer could understand. Reality modeling and 3D technologies allow community members to see details about the project in a format that they can comprehend and provide their feedback. Because 3D reality models can be easily understood, they can accelerate the decision-making process and improve project team collaboration from design through construction. Digital delivery is helping make the goals of Complete Streets viable and more successful. Bentley users have been implementing Complete Streets in projects of varying sizes and geographies, whether they are called Complete Streets or another term. Hear from engineering consultants Foth and JMC2 about how they have incorporated Complete Streets features into recent projects.

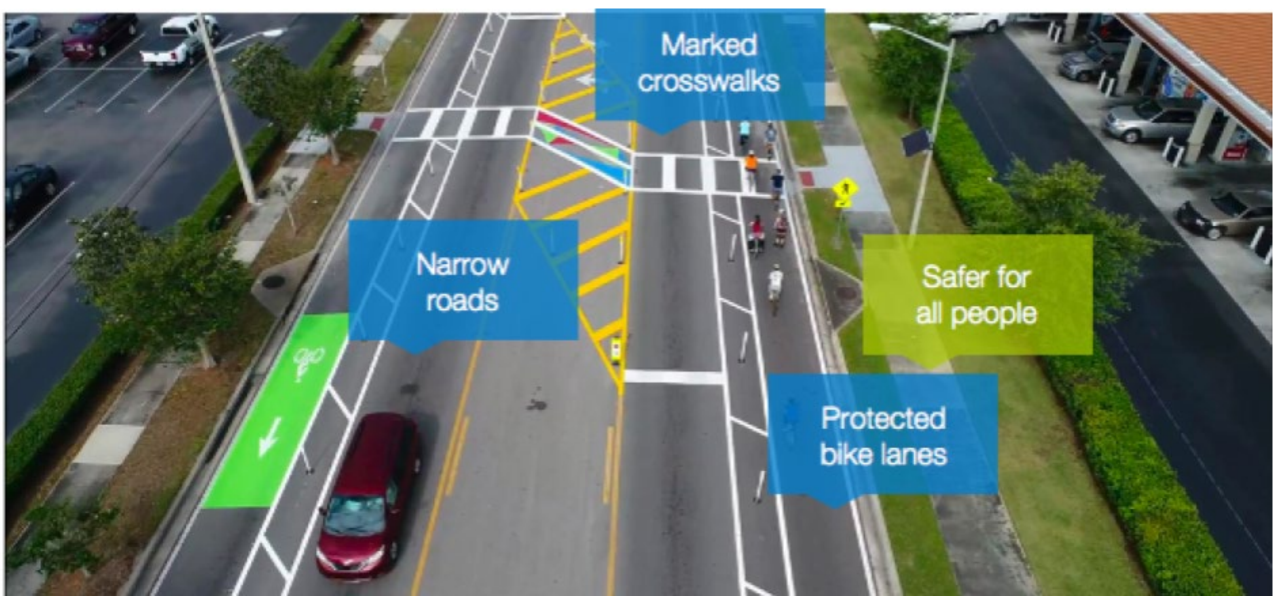

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Image Caption: A Complete Streets approach can include marked sidewalks and bus lanes, protected bike lanes, and accessible pedestrian signals. *Image courtesy of Smart Growth America.*

The Benefits of Digital Delivery and Digital Twins

Innovative technologies and processes can help owners and their partners do their jobs better and faster. One such process is digital delivery, where projects are delivered using digital models, data, and supporting field tools for roadway design, structures design, and construction. Digital delivery and digital twins incorporate streamlined processes to manage asset information as it changes through project development. All project elements are contained within a digital model that can include 2D and 3D model elements with attached attributes and references. Contractors and construction inspectors can use digital models on the project site, and the as-built deliverables are an accurate representation of the constructed project.

Digital delivery makes it easier to review the design intent and develop high-resolution 3D visuals, providing improved design quality. It can make a significant impact on reducing project cost overruns, and the 3D design enables designers to test what-if scenarios to refine constructability and optimize project cost. It improves design efficiency, and contractors can benefit from a more complete representation of the design intent delivered in a more directly usable format, enabling enhanced construction planning and less time to extract information. Lastly, digital delivery improves as-built records, saving valuable time. Instead of marking up PDF plans, contractors will collect digital as-built records.

Advanced Technologies: AI/ML and Remote Monitoring and Sensors

Infrastructure owners are often tasked with monitoring vast and challenging geographical areas with limited human and budgetary resources. With historic levels of bridges in disrepair, new funding, and limited human resources, these owners and their supply chains need to embrace new technology to close the execution gaps. Digital tools, techniques, strategies, and methodologies can streamline processes and enable collaboration across the supply chain. One such example is the technological leap through the proven use of digital twin technologies. Reality data capture using drones and photogrammetry in the field has enabled users of all industries and sizes to easily generate as-operated digital twins of their existing inventory for visualization and coordination with their stakeholders.

Combining reality data with 2D/3D BIM design creates the foundation for operational digital twins where change over time can be tracked. Artificial intelligence/machine learning (AI/ML) analysis can assist with condition assessments and predictive analysis by automatically detecting and quantifying defects and monitoring change over time. The value proposition is further enhanced by adding standardized and agnostic Internet of Things (IoT) data streams to the asset in a digital twin, thereby providing a truly dynamic experience that offers unique solutions tailored to each asset. Cloud-connected technology can be applied to legacy sensors, saving a significant amount of time and money. Automated, cost-effective, and secure, IoT-based condition monitoring solutions are an efficient way of gaining the kind of data that allows asset owners to manage risk responsibly and ensure public safety.

Using dynamic-sensing IoT devices allows organizations to cost-effectively measure the performance of assets, such as bridges, in real time. Powerful cloud-based algorithms transform the sensor data into detailed structural performance metrics under various traffic loads and environmental conditions—providing valuable insights into the health of the structures. Incorporating these rich condition monitoring data sets, along with inspection and defect detection technologies in a digital twin, can improve the ability to target remediation efforts to the most critical structures and ensure the ongoing safety of the traveling public

Combining various data streams into a 3D view along with an interoperable platform unites all stakeholders maximizes design and operations and maintenance (O&M) efficiencies, as well as reduces known and unknown risks and costs in a measurable way. The use of digital twins enables owners to gain real-time health monitoring insights, virtualize routine inspections, and streamline collaboration across operations, design, and construction.

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Image Caption: Digital Twins: The Backbone of Infrastructure Decision-making. *Image courtesy of Bentley Systems.*

City of Perry Innovates with Foth Creating a Digitally Mapped City Using Digital Twins

The City of Perry hired Foth to evaluate street and sidewalk conditions using mobile LiDAR scanning to improve access for citizens. A driving reason for the collaboration was Foth's ability to evaluate all pedestrian ramps for ADA compliance, eliminating the need for city employees to evaluate ramps in the field on an ad hoc basis. Of particular interest for Perry officials was Foth's best-practice of leveraging existing data via digital twin technology to rapidly develop projects to secure government funding opportunities. In a community of 7,800 people, demands are high but the planning and engineering department has limited resources. The project quickly morphed into a citywide digital twin project to support the city's capital improvement plan (CIP), presenting technical challenges for digitizing over 60 miles of streets and 10 miles of alleyways. Foth needed integrated technology to process voluminous geospatial data, aerial images, and point clouds, and provide digital accessibility to multiple stakeholders.

Leveraging Bentley's open modeling applications, Foth developed an optimal plan to deliver the digital twin, saving significant time and potential rework. The 500-gigabyte 3D city model contains approximately USD 598 million worth of asset data. The digital twin provides potential investors with a portfolio of data about historical structures, making them more inclined to invest in Perry and helping increase private investor engagement by 50% over the next five years. Having a digital twin enables Perry to gain support and enact its CIP 60% faster, increasing its ability to secure city funding by 75%.

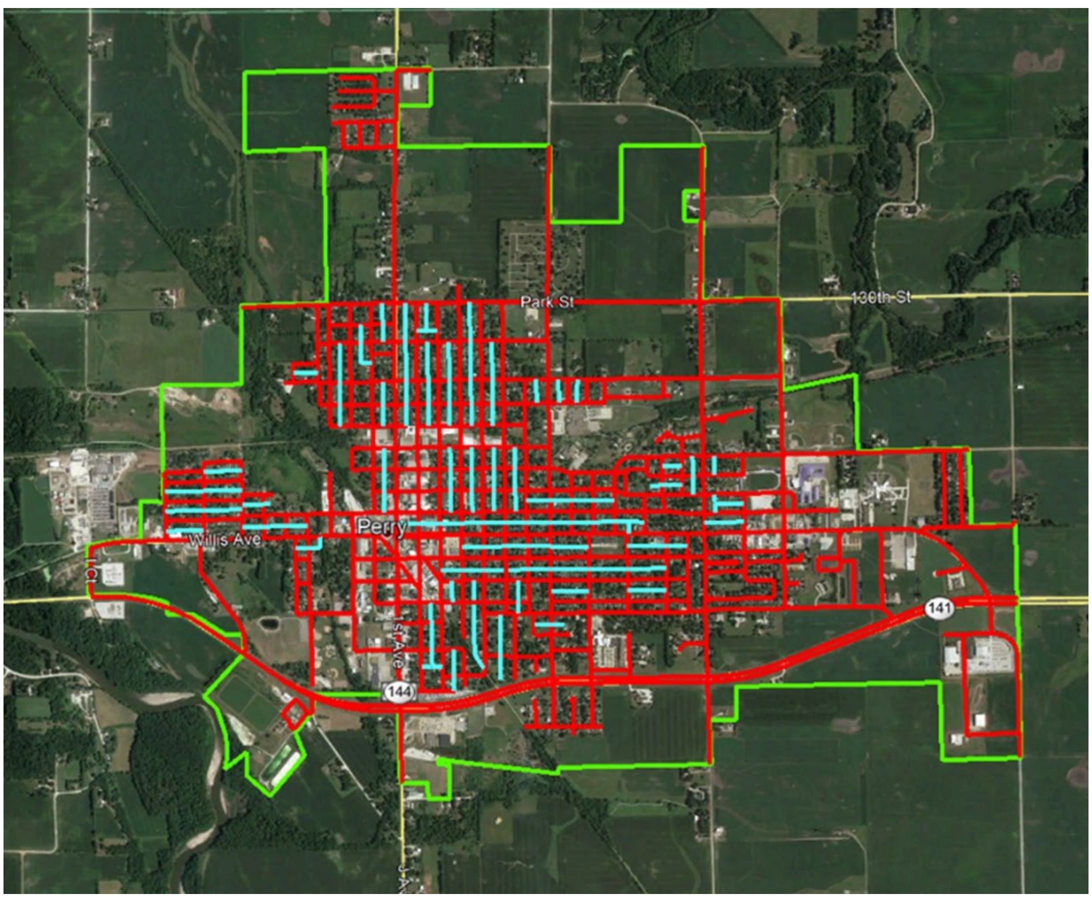

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Image Caption: City of Perry Scan Route. *Image courtesy Foth.*

Takitimu North Link, by Waka Kotahi and FH/HEB JV, Beca Ltd., Tauranga, Western Bay of Plenty, New Zealand

The Takitimu North Link project is being constructed in two stages by Waka Kotahi (New Zealand Transport Agency) and upon completion will offer more varied public transport and improved safety in the Western Bay of Plenty, supporting economic development and population growth. Stage one is a 6.8-kilometer expressway, including 10 bridges and a separated pedestrian path, being built by a Fulton Hogan/HEB Joint Venture, in a challenging natural environment constrained by existing infrastructure and residents. The area is largely volcanic in origin and groundwater levels are shallow in low-lying floodplains and deep in higher-elevation areas. The project team needed to find solutions to rapidly create a road design in these challenging conditions, meet the needs of Waka Kotahi and the community, and communicate and collaborate with the construction partners while minimizing risk. Beca is the lead design consultant and wanted to implement an integrated, model-based digital delivery approach to address the site complexities and coordinate the large, multidiscipline project team.

Leveraging Bentley's open modeling applications, Beca established a connected data environment and digital twin that will simplify construction in the constrained location. Through collaborative digital modeling and 3D visualization, they reduced modeling time by 15% and improved design efficiencies by 20%, while achieving higher-quality deliverables compared to previous design methods. The digital twin enables data integration for construction activities and future management and maintenance of roadway operations.

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Image Caption: Takitimu North Link: Minden Gulley Bridge. *Image courtesy of Beca.*

National Highways Business Information Framework, National Highways, Birmingham, West Midlands, United Kingdom

National Highways is the government organization charged with the design, build, operation, and maintenance of the Strategic Road Network in England. As part of the Smart Motorways initiative to drive collaboration, streamline information sharing, and reduce risks delivering road improvements across England's Strategic Road Network, National Highways (NH) is delivering their Business Information Framework (BIF). A major element of this undertaking are road improvements over the next 10 years including increasing lane capacity across the Strategic Road Network.

This initiative needed to drive collaboration and knowledge sharing, improve productivity, reduce safety risks and improve quality. Faced with data silos and manual manipulation resulting in limited access and erroneous decision-making, NH and their partner want to provide enterprise, web-based data access to project disciplines and stakeholders.

They selected BCDE and the Bentley iTwin platform to establish a digital twin, making federated 3D design and asset data accessible via links with ProjectWise and AssetWise. The

Bentley-based BIF improves productivity, design efficiency, and decision-making, while shortening project schedules. Through open asset data and re-use of data assets, they estimate saving GBP 70 million. Using the digital twin model to integrate asset and document data, the BIF solution already reduced design hours and avoided rework, serving as a key enabler of the Smart Motorway Initiative being rolled out across major projects.

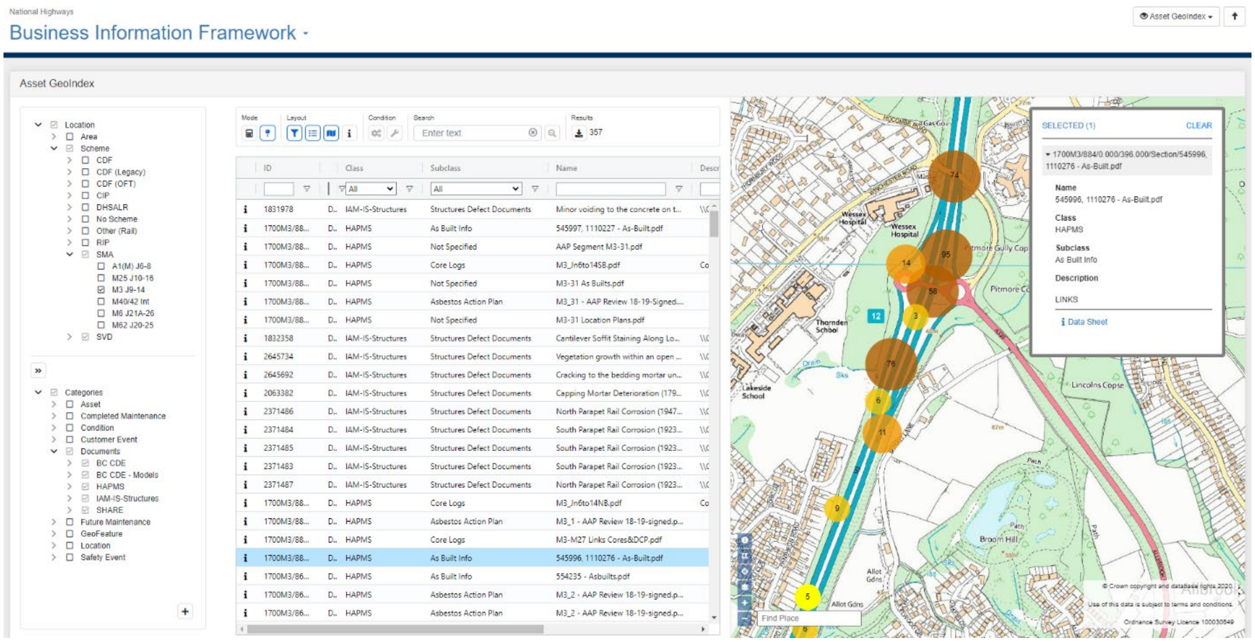

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Image Caption: National Highways Business Information Framework. *Image courtesy of National Highways.*

Interstate Bridge Replacement Program, WSP USA, Portland, Oregon and Vancouver, Washington, United States

The Interstate Bridge Replacement Program (IBR) will replace a 100-year-old bridge connecting Oregon and Washington across the Columbia River with a modern, seismically resilient, multimodal structure that provides improved mobility for people, goods, and services. The project must address environmental concerns for fish and wildlife in the two-state area and preserve archeological resources. The project includes tackling limited public transportation, impaired freight movement, inadequate bicycle and pedestrian facilities, safety concerns with existing roadway design and growing travel demand and congestion. WSP is the general engineering consultant and wanted to implement digital twins throughout the lifecycle of the project. Faced with coordination challenges engaging with contractors, the public, and government entities, WSP needed an integrated digital delivery platform.

Digital twins will define the lifecycle of the program from concept to design, into construction and then hand over an operational BIM integrated asset management model to the owners. Digital twins provide contextual awareness and data-driven insights for more informed decisions and better outcomes. By reducing risk in the design phase prior to construction, minimizing the amount of construction modeling, and digitally planning maintenance and resiliency while maximizing safety through operational activities, WSP estimates saving USD 470 million on the IBR program utilizing an iTwin centric workflow. Compared to traditional project delivery methods, they will nearly eliminate remodeling efforts during construction and realize a 90% reduction in operational inspection activities. During design and planning, for the carbon footprint analysis alone, they expect a 67% reduction in costs.

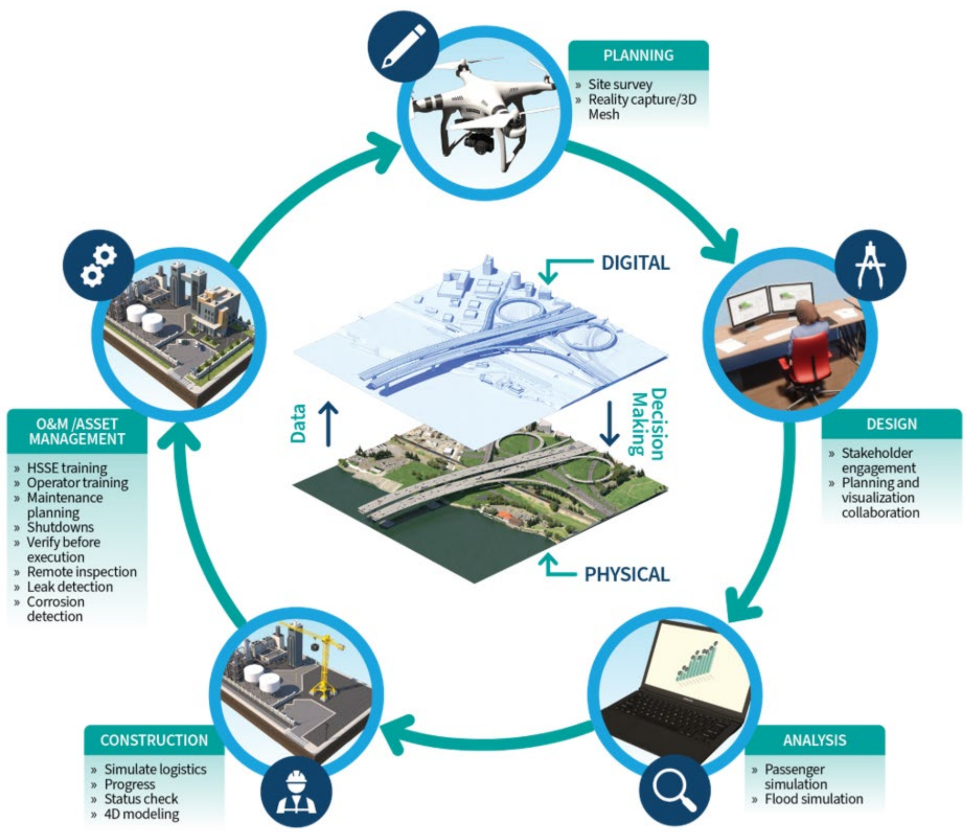

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Image Caption: IBR Digital Twin Lifecycle. *Image courtesy of WSP.*

Conclusion

While transportation owners and their supply chain face numerous challenges of how to plan, design, construct and operate safe, resilient, and sustainable infrastructure, there are technology solutions that can help address many of these issues.

We have seen owners and their partners apply innovative approaches to addressing aging infrastructure, growing population, and increased traffic and congestion through the use of digital twins and digital delivery, gaining insights for design and construction, virtualizing routine inspections, and streamlining collaboration across operations, design, and construction

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