# REAL-WORLD SOLUTIONS USING GEOSPATIAL MODELS: TRANSPORTATION

## Geospatial technology enables transportation problem solvers to use reality as their greatest asset

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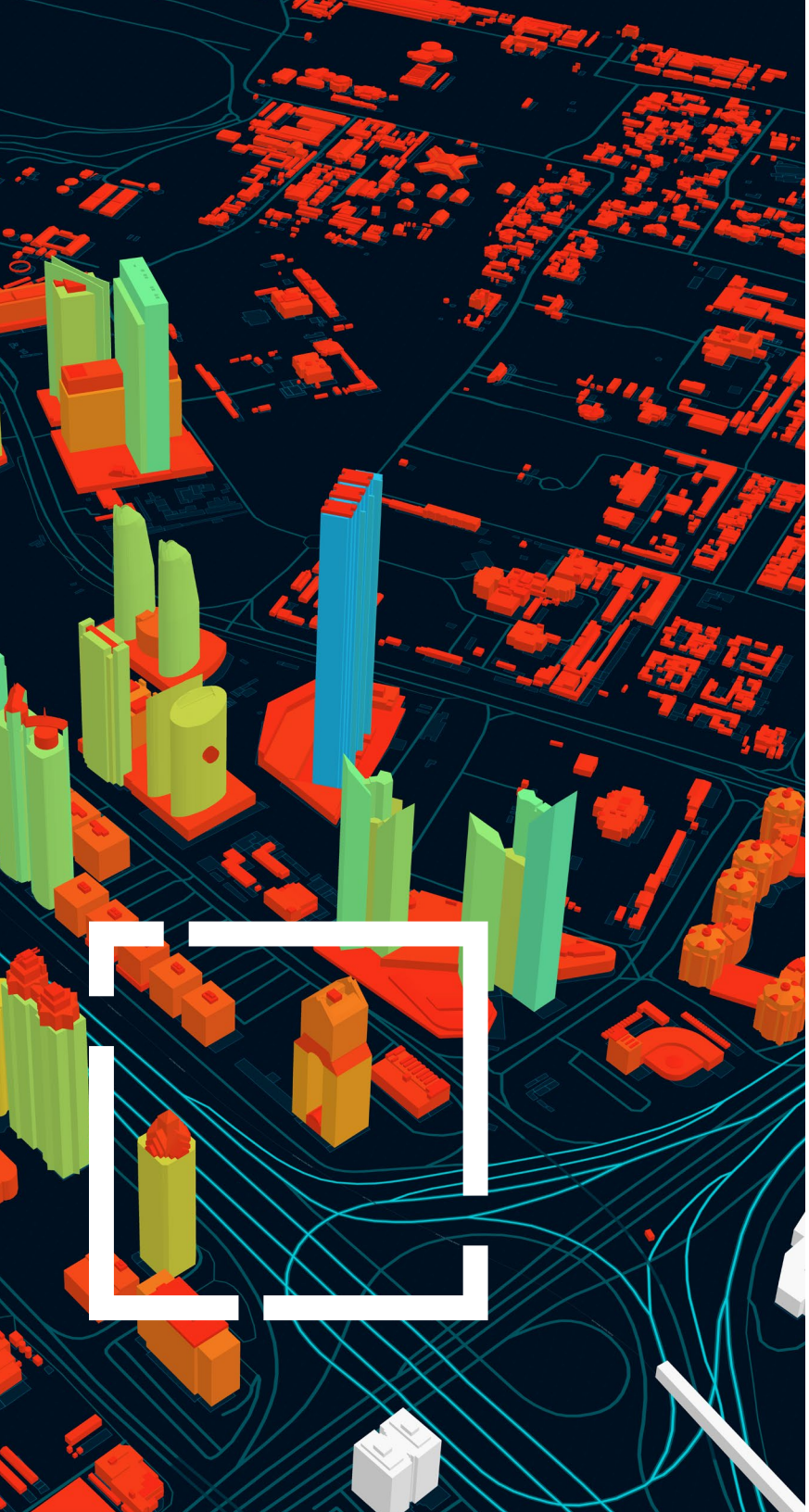


## WHAT'S INSIDE

# Executive Summary: The Geospatial Imperative

Geospatial technology is an integrating force for data and analytics with benefits that can be understood and applied across every organization. Today's geographic information system (GIS) platforms enable unprecedented visibility into the physical world and the people who move within it.

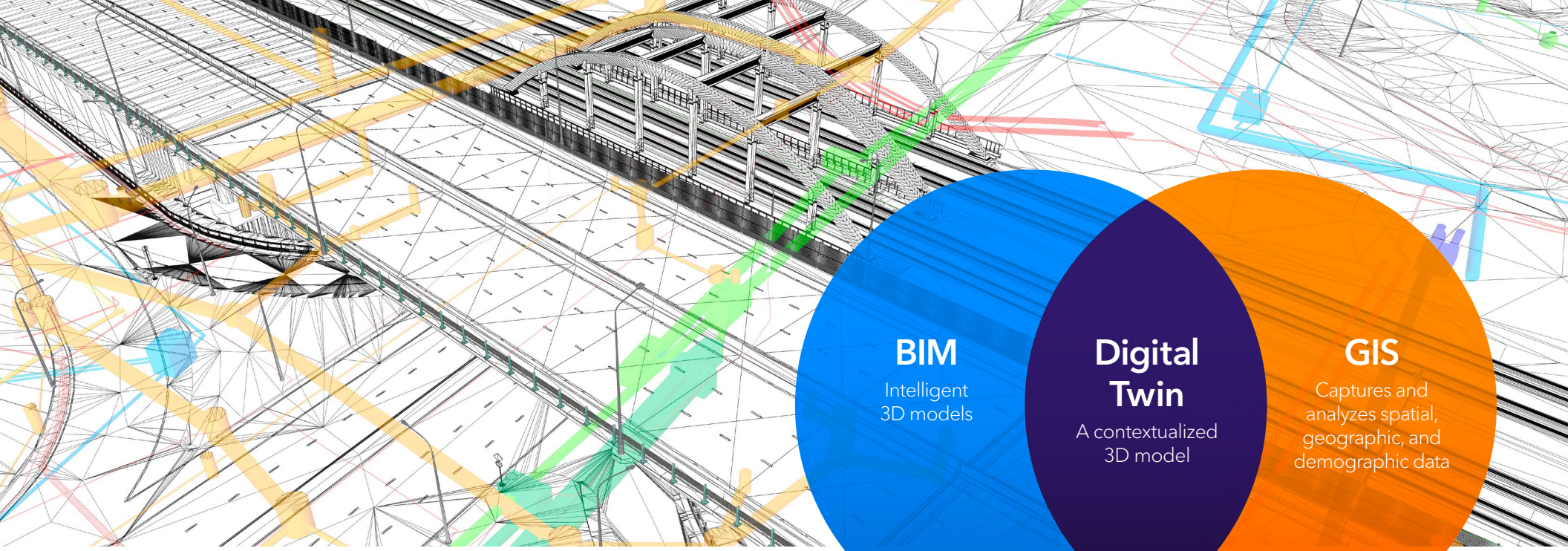
Geospatial infrastructure provides data aggregation that acts as a single source of truth for an entire project, enabling holistic integration of people, data, and technology.

**People:** Team members, business units, and customers can seamlessly collaborate and share information.

**Data:** Organizations can collect and store millions of points of data within a collaborative environment.

**Technology:** Grounded in the real world, GIS acts as the foundation for a project. Integrations with Autodesk and Microsoft enable team members to use blended data to improve workflows and solve real-world problems in a digital environment.

Through this emerging geospatial infrastructure, users can now inexpensively and efficiently access massive amounts of geographic data. Community members can easily share maps, analytical models, applications, and workflows across and among multiple users and organizations. The result is a secure but highly collaborative environment where integrated deployments are focused on shared goals. ■




The Geo-BIM Alliance

SECTION 1

# THE GEO-BIM ALLIANCE AND THE POWER OF THE DIGITAL TWIN

A fusion of technologies is blurring the lines between the physical, digital, and biological spheres—making a new source of truth for an entire project. Most significantly within the architecture, engineering, and construction (AEC) industry is the growing connection between building information modeling (BIM) and geospatial, or geographic information system (GIS). Far more than a niche technology, GIS is relied on across industries for managing, mapping, modeling, analyzing, and sharing authoritative data in the crucial context of location.

By adding GIS and BIM, planners can develop a digital twin to see a proposed project from any angle within the environment it will inhabit.

Looking at a digital twin, stakeholders can quickly see a project modeled with interrelationships such as terrain and structures (including underground utilities), saving time and avoiding mistakes. Planners can use the Geo-BIM fusion to see a 3D model in the context of its precise location and test components and system functionalities before breaking ground—which can prevent rework and cost overruns. Models become increasingly realistic by gathering input from multiple disciplines and allowing other teams to access geospatial data as well.

Since an enterprise geospatial infrastructure operates within a cloud environment, globally dispersed teams are able to collaborate remotely within the same digital twin environment. This means disparate stakeholders can share data, workflows, and software for accuracy and consistency throughout the project. ■

# HIGH SPEED 2 RAIL PROJECT/ UNITED KINGDOM DEPARTMENT FOR TRANSPORT

The United Kingdom Department for Transport has embarked on a world-leading infrastructure project. By the 2030s, London will connect to Birmingham, Leeds, and Manchester via a new rail line with 18 trains per hour traveling at speeds of up to 225 mph. The line, High Speed 2 (HS2), builds upon the more than 15-year success of HS1 which carries 20 million passengers per year through the Channel Tunnel to and from Europe.

HS2 promises to drive economic growth, redistribute opportunity to the north of England, and support towns and cities across the UK. It will cut the travel time from London to many northern cities by nearly half while moving people and goods in a way that's efficient and eco-friendly.

A project of this complexity and scope requires new levels of planning and design. It requires the integration of two key technologies: building information modeling (BIM) and a geographic information system (GIS).

GIS data specialist George Floros works with the Skanska, Costain, and STRABAG Joint Venture (SCS JV), the group responsible for the London-portion of HS2 construction. In building the rail line from the center of London to northern parts of the city, Floros notes, the "densely populated environment makes BIM and GIS integration critical." ▶

## Digging through the Heart of London

Approximately 90 percent of SCS JV's rail line contract work will take place underground in the heart of London. Keeping people and commerce flowing while the HS2 project threads through the city over a five-year span will prove challenging. It's imperative that the team has accurate data about where current structures, pipes, and cables are located.

"If you understand exactly what exists before you try and build something, you avoid accidents," Floros said.

Floros and his colleagues use GIS to visualize details about the location of above- and below-ground networks and to analyze how different elements interact with each other. They use BIM to get a model of buildings and structures with details pertinent for the full life cycle of the project.

"GIS can't get into as much detail as BIM, and on the other hand BIM cannot bring together the surrounding context," Floros said. "An integrated 3D GIS-BIM environment, that we call GeoBIM, combines strengths and eliminates any weak points."

Floros has been working on GIS-BIM integration since 2014 and has developed algorithms that automate data conversion in GIS, BIM, and computer-aided design (CAD) formats so that all information can be accessed in a common visualization environment and to provide a data exchange platform.

"A shared platform allows anyone working on the project to use and access the geography of HS2," said James Gasson, GIS manager at SCS JV. "Everyone has a 'shop window' to browse all the data available to them." ▶

## Improving Information Flow

Before they can begin construction, the design plans must be thoroughly vetted and approved. Right now, planning for construction is well under way.

"New applications for GeoBIM are constantly being introduced by multiple teams in the project, well beyond the use cases imagined before the release of this environment" Floros said. "Just the other day, a colleague from the construction team remarked, 'This environment really helped me to understand where I should place a crane, based on the surrounding context.'"

In addition, everyone involved in planning can see individual designs for the entire project. This level of awareness excites Floros. "On such a large project, it's very hard to understand all the individual elements you're going to build from the aggregate of spreadsheets and documents," he said. "Seeing designs placed together within the context of the city of London immediately helps you understand. You get a wow in your mind–this is what I'm building!"

The power of visualizing the whole scope of the project in 3D has also improved communication and community engagement.

"We recently used the model in a community event in central London to demonstrate to residents that the construction would not impact existing views," Floros said. "The model provides evidence. It's not just saying, 'Don't worry, everything will be fine.' We prove it and demonstrate it using scientific methods, which is the best argument." ▶

## Adding Dimensions

The move to embrace 3D data in GIS provided the path for closer integration with BIM and CAD. Pioneering firms like SCS JV are pushing into additional dimensions.

"I'm working with our 4D specialists from our BIM team to integrate time and construction sequence," Floros said. "It's a very interesting challenge. We have the information from the planners—it's a matter of bringing that information into our 3D GIS system."

Moving beyond 3D and even 4D, the architecture, engineering, and construction (AEC) industry has standardized a vision for several next dimensions: 5D for quantities, cost estimation, and budgetary tracking; 6D for energy consumption; and 7D for asset management in operations and maintenance, including component status and maintenance procedures.

"It's not a challenge to make the visualization look pretty," Floros said. "The key is to focus on what questions added dimensions address. The purpose of the shared data platform is analysis, although it also serves visualization purposes." ▶

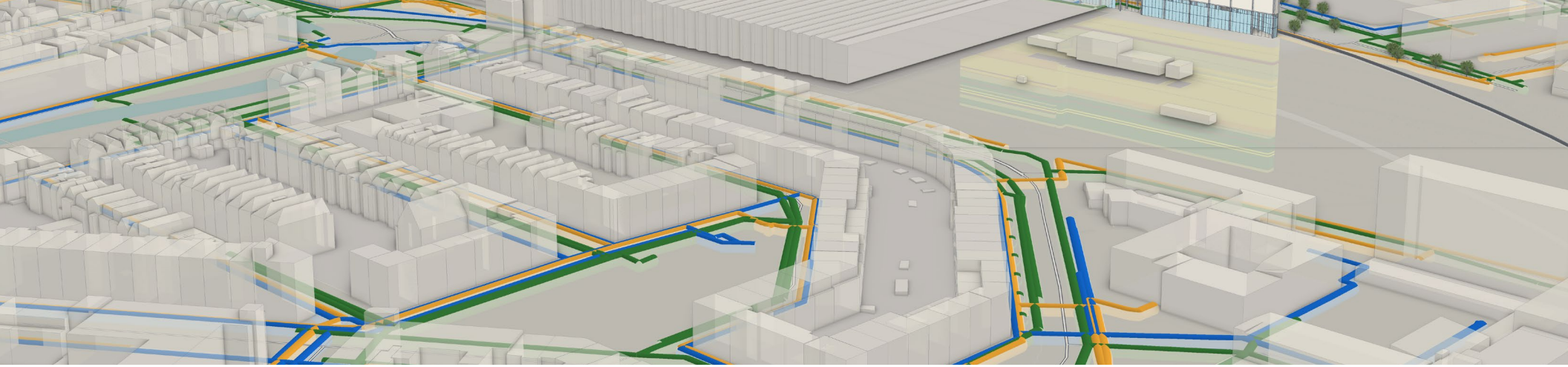
## Rebalancing the National Economy

In the lead-up to the HS2 project, a government report illustrated England's unbalanced economy, citing capacity constraints in the south and poor connectivity in the north.

In consideration for what the UK alone delivers to the world economy, England has pushed a mandate that all its government projects use BIM. With this drive for AEC firms to deliver buildings and infrastructure along with detailed models, the government has spurred UK engineering agencies to take a global lead on digital transformation in the AEC space. This approach aims to keep a handle on costs and address carbon emissions.

The HS2 project and related Crossrail underground connections in London have earned the UK global respect for train modernization and renovation. With many eyes on the project, the ability to integrate data and models; visualize the full scope including construction phases; and deliver a streamlined project on time and on budget will firmly place the UK as a global leader in the delivery of large infrastructure projects.

"I hope that I've explained the advantages of GeoBIM clearly so that you understand the advantage," Floros said. "The moment you see it in action, it captures you, and you can see what's happening. It aspires to be the Digital Twin of the built environment, not just for planning and construction, but most importantly for operations and maintenance." ■



SECTION 2

# TRANSPORTATION MODELS GROUNDED IN REALITY

Transportation agencies have used 3D modeling in building construction effectively for many years. In BIM applications, designers can identify early in the process potential issues with the construction project, such as clashes in future piping, wiring, and HVAC ductwork.

When BIM models are placed within a GIS environment, designers can also identify potential issues the proposed project may have on the real-world environment, including impacts on existing infrastructure, unique geographic qualities, underground utilities, traffic flow, the environment, shadow modeling, and potential noise pollution.

In a 2017 report, a UK-based group dedicated to driving costly errors out of construction found that the industry lost £21 billion—or 21 percent of its annual revenue—to preventable errors like late design changes, ineffective communication, and poor coordination.

Researchers found that project plans often lacked context that could show how a new building would impact the land and structures around it and how those structures and land would impact the building.

The new pairing of BIM and geospatial technology is doing just that—helping planners see relationships between the built environment and planned structures and develop contingencies to avoid surprises during construction.

> "The Geo-BIM alliance helps planners see relationships between the built environment and planned structures to plan for contingencies and avoid surprises during construction."

Fortunately, tremendous advances in geospatial technologies have made these tools far more powerful, accessible, and usable. Employing technologies such as intelligent, real-time GIS to prioritize, plan, and execute new infrastructure projects can help optimize public and private infrastructure investments and avoid inefficiency and waste.

Beyond the physical structures being built, customers also need to understand the impact a project might have on the people who live near it, use it, and fund it with their tax dollars. The massive amount of global construction anticipated to happen in the next 50 years is driving nearly every country to ask how we can positively change the world efficiently and sustainably while meeting societal requirements. Meeting our societal needs will only happen by applying real-world context from GIS with BIM design and construction data to new processes for assessing impact and predicting outcomes. ■


CASE STUDY

# COLORADO DEPARTMENT OF TRANSPORTATION

The Colorado Department of Transportation (CDOT) operates throughout Colorado with regional offices and teams. The entire road system is composed of a subterranean system of culverts, which allow water to flow under a road, railroad, trail, or similar obstruction from one side to the other. CDOT uses an enterprise GIS system to visualize and manage the vast system of subterranean culverts and aboveground physical infrastructure as well as facilitate smarter collaboration and communication among its dispersed team members.

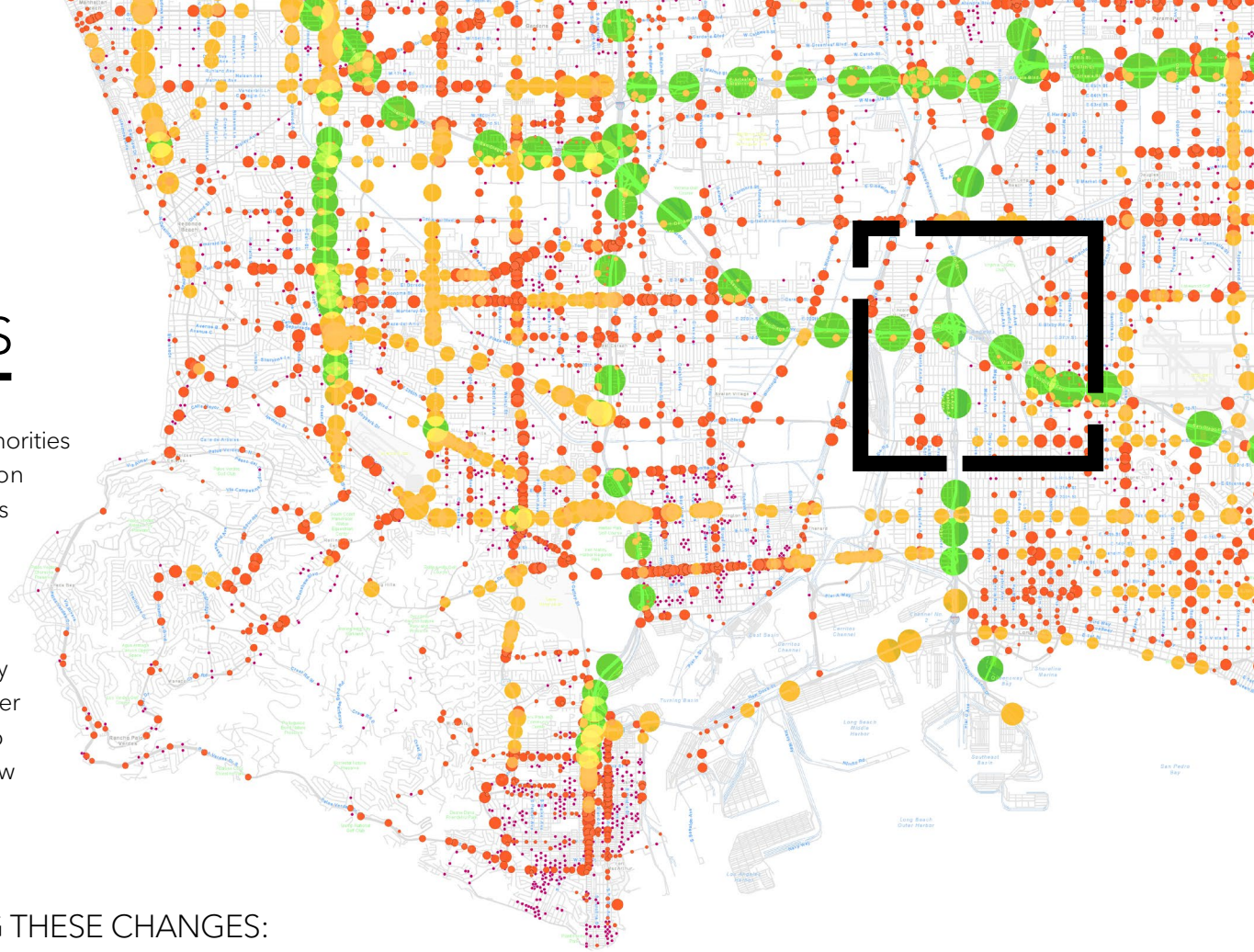
GIS helps CDOT meet internal goals to create more efficient road systems and move people faster. Spatial data helps CDOT answer questions like, Where are the most congested areas? Where are more incidents happening? Answering those questions within a digital twin environment allows CDOT to efficiently deploy solutions in the real world.

Artificial intelligence (AI) is also supporting more informed decision-making related to safety and maintenance. One example is its ability to calculate how many cars have windshield wipers operating in a certain area. That information, communicated via the GIS dashboard, allows CDOT employees to confidently trigger alerts about slippery road conditions and speed reminders. Friction sensors on roadways complete the safety circle by communicating instantly with variable message signs.

Spatial data forms the foundation of CDOTs tech stack. From there, CDOT builds other technologies to help manage improvement projects and infrastructure maintenance initiatives. Its interactive GIS platform allows a user to perform instant spatial queries, without needing the help of a specialist. CDOT also uses data-driven smart maps to visually convey the history of decision-making and garner support for new initiatives with key stakeholders. ■

SECTION 3

# GIS: AN INDISPENSABLE PARTNER FOR CUSTOMERS



As the core business of governmental transportation authorities shifts from construction to preservation, transportation professionals must increasingly manage complex systems under continually constrained revenues and an ever-increasing set of performance expectations from the public.

These trends are occurring in the context of a dynamically changing regulatory environment, which requires a greater emphasis on comprehensive information systems to help support better decision-making regarding where and how scarce public resources are allocated.

## HERE ARE FIVE KEY FACTORS ACTIVATING THESE CHANGES:

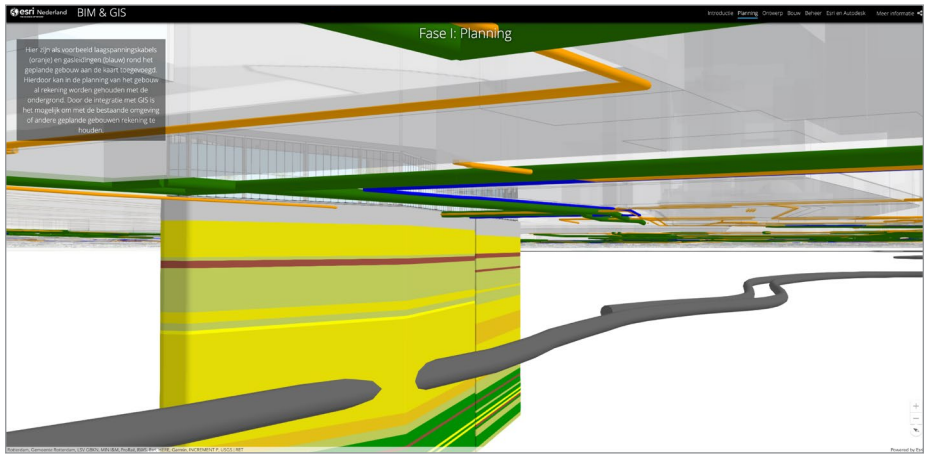
**Requirements for Data-Driven Decisions:** New regulations require transportation planning to be driven by decision-making processes that rely on crucial information systems and defensible analysis.

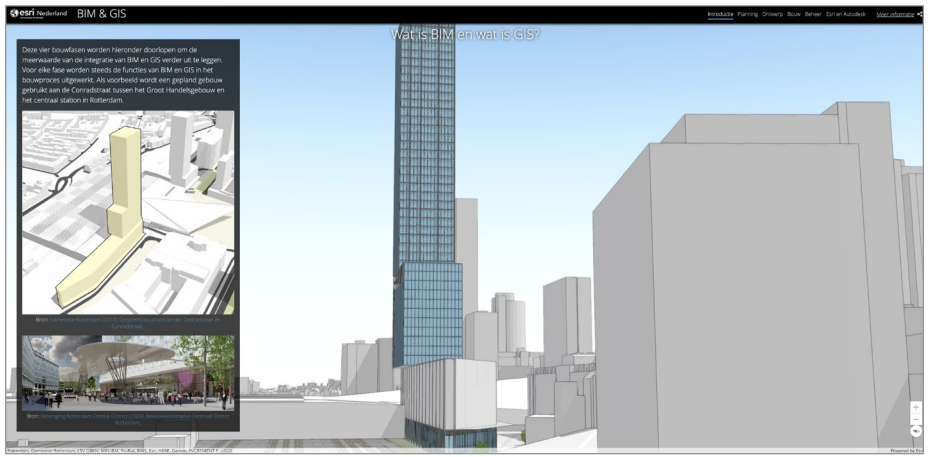
**Move to Performance-Based Planning (PBP):** A performance-based approach to transportation decision-making that supports national performance goals related to safety, mobility, goods movement, preservation, and environmental sustainability is expected.

**Required Risk-Based Asset Management Plans:** Transportation agencies need to demonstrate a focus on preserving core transportation assets and include a life cycle cost and risk management analysis.

**Comprehensive Planning Approach:** Interagency barriers need to be overcome to maximize the return on taxpayer investments by employing smarter planning protocols.

**Need for Greater Public Transparency:** There is a growing public expectation of greater transparency in the way public dollars are spent. ▶

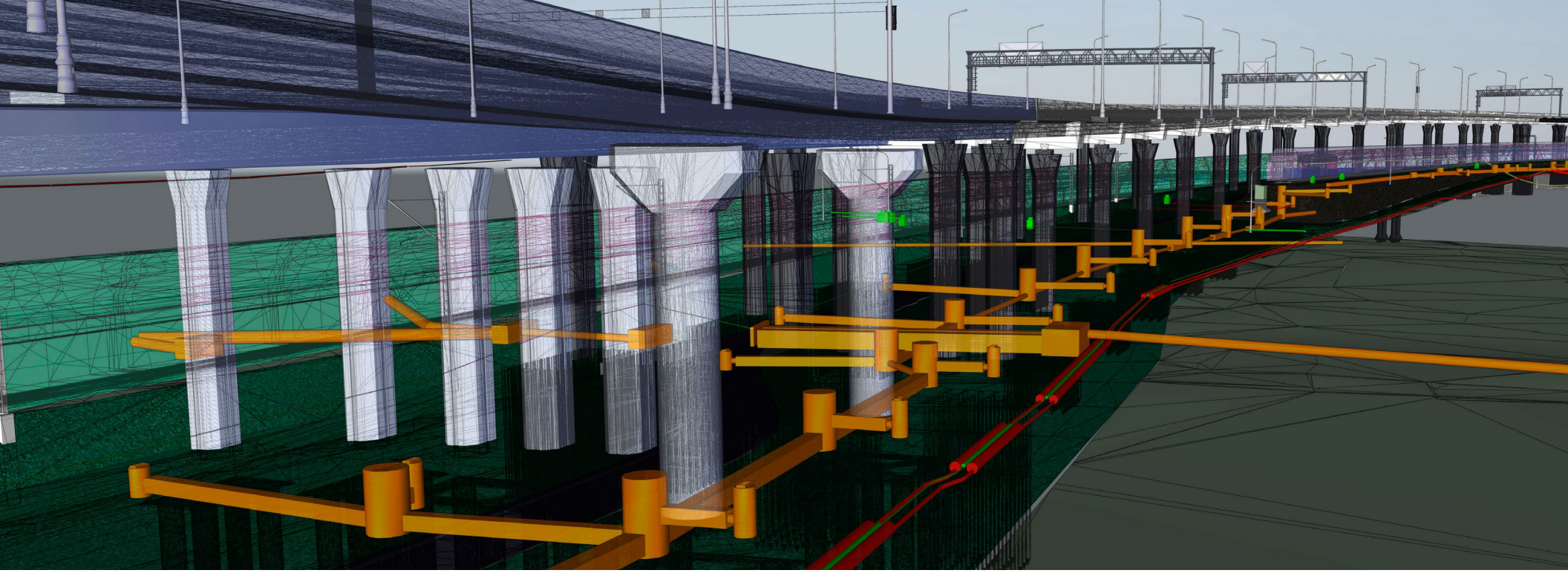




## Section 3 (continued)

For AEC firms to help customers meet new regulatory requirements and support evidence-based decision-making, they must provide a seamless way to transparently share data and employ comprehensive planning grounded in reality. In the past, transportation plans were often presented to stakeholders and the public in documents filled with technical jargon and presentation formats that nontechnical readers couldn't understand. A geospatial approach solves these problems, making a GIS-savvy AEC firm indispensable to its customers.

For instance, planning professionals can use multimedia presentations called Esri Story Maps℠, which combine high-quality graphics, maps, text, and videos to present each element of a plan. These interactive communication tools convey technical information in an easy-to-digest way to key stakeholders and the public.

Firms can securely collaborate with stakeholders, contractors, clients, or any outside party, all within a controlled environment, using GIS project delivery tools. They can view and edit workflows and assets in real time throughout a project's life cycle. An additional benefit is gaining contextual intelligence since the history of decision-making and project components are all stored in one place. ■



CASE STUDY

# JACOBS FOR HIGHWAYS ENGLAND

Jacobs' longtime client, Highways England, identified the need for data and digital products to be delivered in a new way. Traditionally, 3D design data was stored as BIM design files when it was issued, but the client was finding that access to product deliverables was limited and understanding was restricted to only those with CAD software knowledge. Many team members didn't find the information easily available, and they weren't able to visualize or analyze the project the way they wanted and needed to.

As part of the Highways England project, the team had already created a GIS portal to share geospatial information with the client. At the time, they were using it to share smart maps, Esri Story Maps apps, and other location intelligence data. They began to look for a way to allow their client to easily interact with and interrogate 3D CAD data within the same web-based GIS environment.

To make BIM data more available to visualize and access, they created an automated CAD data processing workflow within GIS. This allowed users to easily view proposed 3D design against other project datasets with the capability of viewing individual features and utilizing them for decision-making. An added benefit was the ability to apply changes simultaneously to multiple files and multiple projects for future use.

The team used their enterprise Portal for ArcGIS® to process and share the massive amounts of project data. It also allowed them to easily tap into the British National Grid to map the location of subsurface underground utilities and layer it with other geospatial data like topography and elevations.

The process and data sharing efficiencies achieved by these changes have allowed Jacobs to save considerable time and money for its client. ■


SECTION 4

# A UNIFIED PROJECT MANAGEMENT SYSTEM: SAVING TIME AND MONEY

As larger companies adopted GIS, it was initially applied to the work of individuals or groups and later to entire departments. The vision of enterprise GIS sees all these systems as integrated and supported by a single unified database and associated software—a system of systems.

An enterprise GIS uses a single, universal language to describe geospatial features and their interrelationships, helping break down barriers to communication that always emerge in a segmented or stovepiped organization. This allows users to create a single source of truth that is trusted throughout the organization and among customers—united through location.

While this unified view is valuable for everyday business activities, it is especially valuable in helping guide the project planning process. Through GIS, information from transportation models, asset management systems, roadway inventories, and transportation monitoring systems can all be brought together to support the entire planning process. Having all relevant data and information sources easily accessible and centrally located minimizes frustration.

Mobile apps provide a useful collaboration tool, letting users access shared views and information at any location and on any device. Apps extend the reach of administrators, showing where technicians are and what they're working on, and engineers, allowing work to be reviewed or fine-tuned as it's happening.

Workflow management capabilities allow project managers to assign tasks to different people, control editing privileges, and manage geospatial product outputs in a centralized database. Since project data is aggregated, organized, and analyzed within a unified interactive environment, users can quickly and easily choose to dive deeper to see documentation, scanned maps, ordinances, history, and why changes were made. ■

CASE STUDY

# LOS ANGELES INTERNATIONAL AIRPORT

Los Angeles International Airport (LAX) is the world's fifth-busiest airport for passenger traffic, having served more than 88 million people in 2019. Incremental improvements to the airport and its transportation network failed to keep up with its growth over the years. In 2010, a major capital improvement plan, known as the LAX Development Program, was implemented.

The $15 billion three-phase project is the largest public works initiative in Los Angeles history and will be completed in 2028. It is strategically leveraging a modern GIS not only to streamline the workflows of multiple construction projects but also to ensure that 24-hour-a-day airport operations proceed smoothly.

The project will include upgrades to all passenger terminals, a consolidated car rental facility, and a transportation hub to link light-rail service to the airport. One of the most exciting features of the plan is an automated people mover that quickly transports passengers from one terminal to another. The driverless electric train will accommodate 10,000 riders each hour. ▸

## LAX (continued)

The modernization initiative includes uninterrupted service for the more than 65 million passengers it serves each year. This means that services must be diverted to other areas. For instance, moving an airline to another terminal requires planning all the elements around such a move, from ticketing to elevators. Another task is coordinating the efforts of 130 projects happening at once. Where are projects located, what are they doing, and what stage are they in? These logistical challenges require geospatial insight.

Los Angeles World Airports' (LAWA) Coordination and Logistics Management (CALM) platform combines a geographic information system called Airport Enterprise GIS (AEGIS) and a document management system to help managers oversee the airport's multiple construction projects. Staff and stakeholders use the system to access all construction records and drawings. The GIS displays project locations and provides a geospatial interface for data.

CALM manages 500,000 documents and creates logistic coordination maps based on the most up-to-date data. Spatial analytics helps LAWA carefully coordinate projects, making sure that one project doesn't interfere with another or severely impact airport operations. Visualizing information with GIS makes it easier to see any conflicts among project schedules and locations. By recognizing potential problems before they happen, LAWA lowers project contingencies, risks, and costs. ■

SECTION 5

# THE BUSINESS VALUE OF A MODERN TECH STACK

Armed with the right mix of technology, an AEC firm can establish itself as a leader within the transportation industry, driving innovative solutions for customers and society.

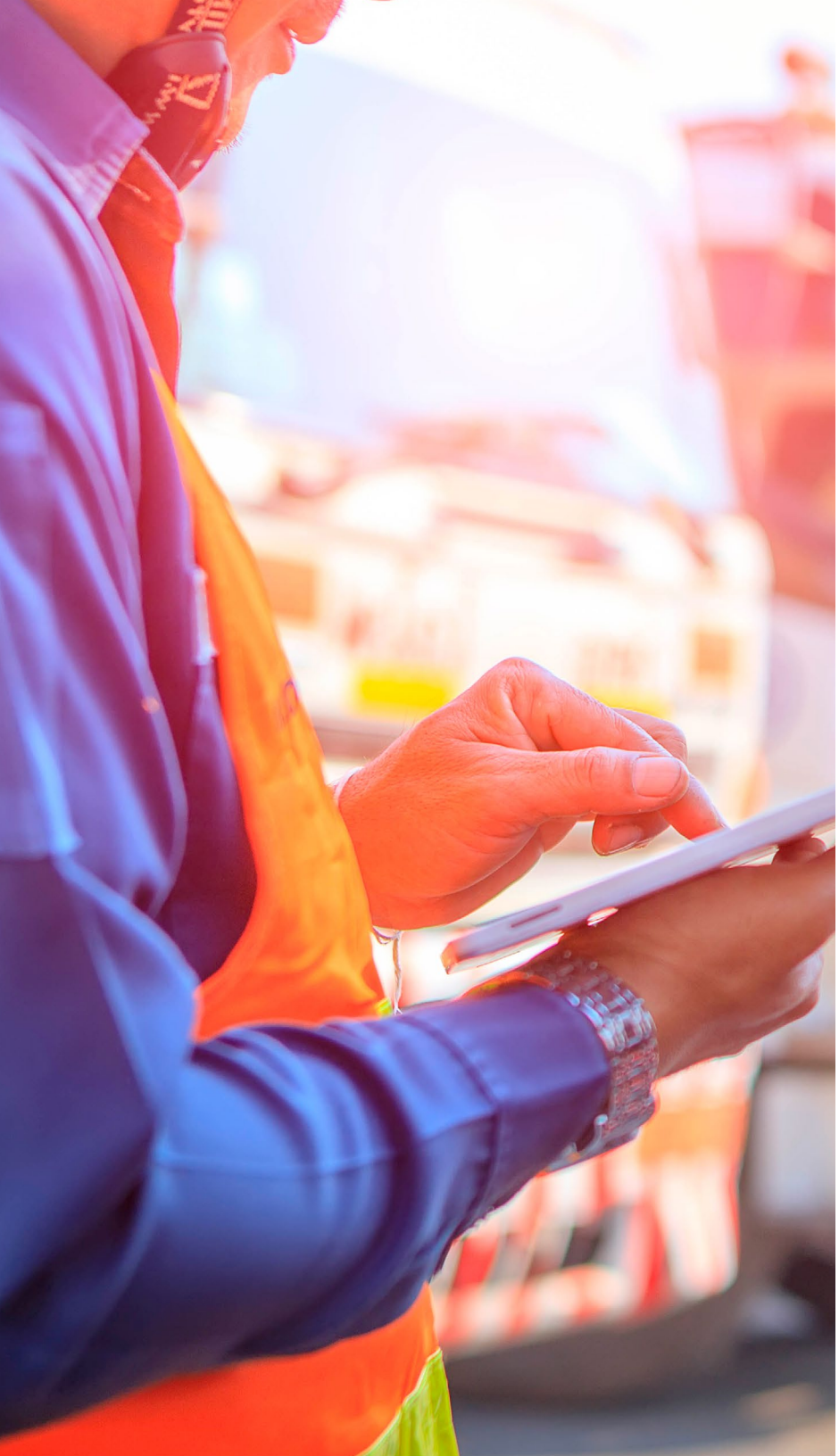
For intelligent decision-making based on up-to-date, real-world conditions, firms can build their modern tech stack—one that includes the Internet of Things (IoT), AI, imagery, and crowd-sourced data—on the foundation of their GIS. This empowers planners to collect data from a near-infinite number of sources, then visualize and analyze it as geospatial information. Within established workflows, teams can enhance their ability to complete tasks and elevate product outputs by integrating Autodesk, Microsoft, and IBM with GIS.

The volume of data being collected from remote IoT sensors is enormous, and most of it is geographic. Besides volume, modern data collection is characterized by velocity, with significantly more data becoming available in real time. Instead of weeks, the delay in obtaining remotely sensed imagery from satellites is falling steadily, and it is possible to anticipate a day when it will be possible to obtain digital representations of the earth's surface as it currently looks, or looked a few minutes ago. Images can be collected and incorporated in real time.

AI tools have had remarkable success in many areas. They allow massive bodies of raw data to be analyzed, looking for patterns and performing simple analyses, and in many cases, outperforming the more traditional tools of analysis, many of which were developed long before the advent of massive computation and big data.

Image analysis provides some of the most compelling early applications of AI to geospatial data. It is able to analyze vast amounts of imagery rapidly, finding features such as streets and roads, classifying infrastructure, and identifying factors indicative of traffic congestion or derailment risk.

The ability to collect crowd-sourced location intelligence via apps and sensors is also opening new and exciting possibilities within the transportation sphere. One company seeking to create a continuously updating "basemap" for autonomous cars has created a compact device that can sit inside a personal vehicle and record street-level 3D imagery. As drivers roll through cities across the country, the device continually updates maps with data from multiple high-resolution cameras—creating a digital twin of road infrastructure. ■



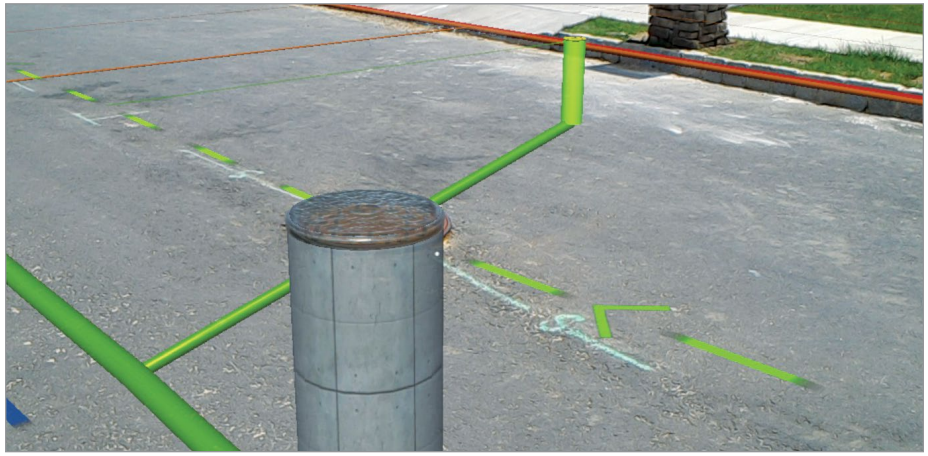
CASE STUDY

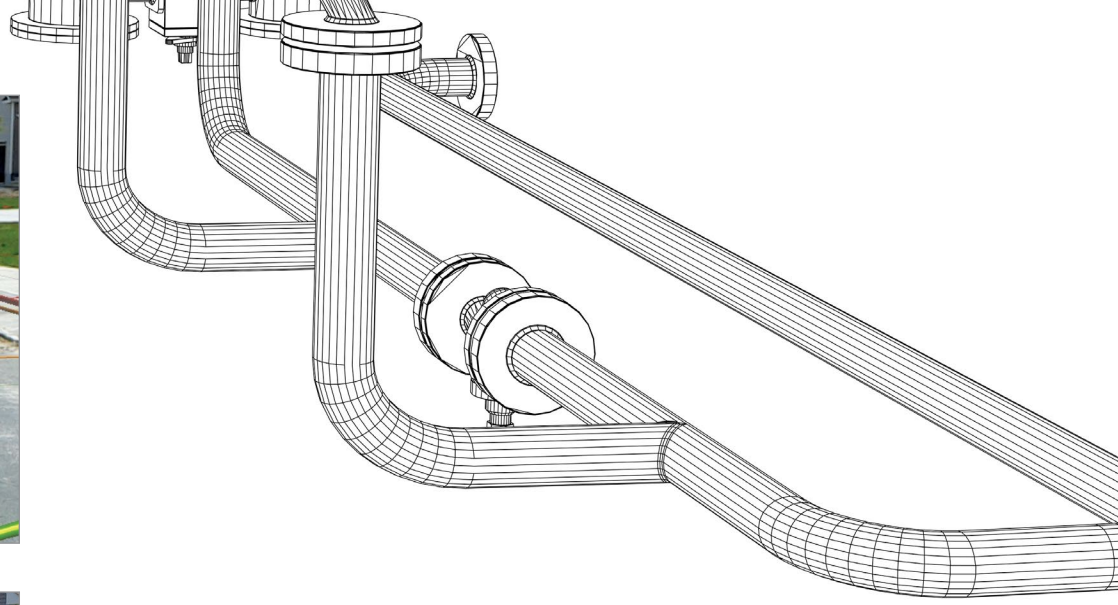
# NEW YORK AREA TOMS RIVER MUNICIPAL UTILITIES AUTHORITY

Toms River Municipal Utilities Authority (TRMUA), located just outside New York City, may just be the first utility in the world to use mixed reality headsets to guide fieldworkers in locating underground utilities. This technological leap brings utilities and other companies with underground assets closer to realizing an age-old wish: to see through dirt. The mixed reality solution is helping field technicians in Toms River close service tickets more quickly and avoid costly repairs.

"This is not science fiction anymore," says Len Bundra, IT/GIS director for Toms River who saw the potential in a mixed reality application.

At its most basic, the Toms River system takes three well-established technologies and combines them into one brand-new application. All three are commercially available—Esri's GIS, which stores location and attribute information on TRMUA's underground assets; Microsoft's Azure cloud computing service; and Microsoft's HoloLens. ▶



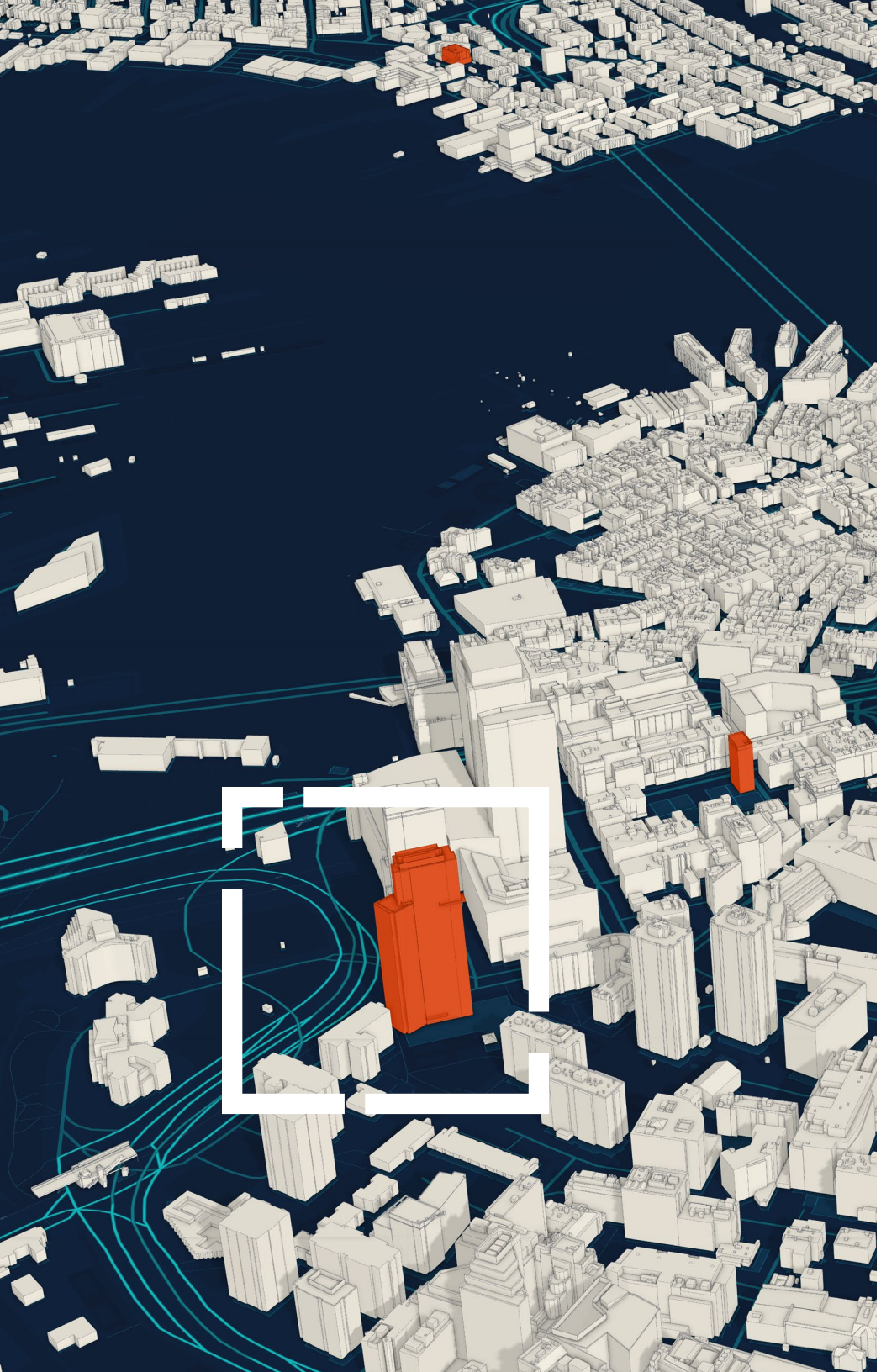


## TRMUA (continued)

The holographic headset includes audio, tiny cameras, movement sensors, and a system for confirming the wearer's exact location relative to the underground pipes. While wearing the HoloLens transparent visor, utility workers see a mixed reality—including the real world in front of them as well as a holograph of the lines of wastewater pipes underground. The pipes are color-coded and projected to scale. With slight movements or audio commands, the wearer can summon screens showing relevant information.

While wearing the headset, workers operate hands free, precluding trips back to the truck to get their bearings using two-dimensional maps of utility lines or a tablet computer. And even more importantly, the technology allows fieldworkers to connect with remote colleagues—often an engineer in the office—who can see exactly what the fieldworkers see. This is accomplished through a simple Skype connection. So if the employee in the field—whether marking lines with paint or digging to fix or replace a line—is not sure how to proceed, an engineer or manager back at the office can highlight or circle certain areas where extra caution should be taken, and those marks will appear in real time on the fieldworker's visor.

As more agencies and organizations realize the potential savings, increased efficiencies, and improved job safety, the use of hands-free mixed-reality headsets may set the new standard for avoiding utility breaks while digging and preventing errors when marking line locations on asphalt, concrete, or lawns. ■



# Learn More

Esri, the global market leader in geographic information system (GIS) software, location intelligence, and mapping, offers the most powerful geospatial cloud available, to help customers unlock the full potential of data to improve operational and business results. Founded in 1969, Esri software is deployed in more than 350,000 organizations. With its pioneering commitment to geospatial information technology, Esri engineers the most advanced solutions for digital transformation, the Internet of Things (IoT), and advanced analytics.

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