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THE SCIENCE OF WHERE™

OPERATIONAL INTELLIGENCE

Location Provides a Common Language to Drive Efficiency

Visibility | Context | Condition | Predictability

WHAT'S INSIDE

Moving toward Predictive Maintenance

Powering Maintenance Intelligence

Work Order Management Systems

Maintenance Situational Awareness

Enhancing Communication and Collaboration

GIS Aids Construction Workflows

Case Studies

Crossrail | Hurricane Sandy | Port of Rotterdam | High Speed 2 | Schiphol Airport

Contextual Intelligence: Moving toward Predictive Maintenance

Many asset-centric organisations fall into the rut of reactive if-it-breaks-fix-it operations. It's a hard pattern to change, even knowing that fixing things when they break is three or four times more expensive than adopting a preventative maintenance approach that anticipates failures.

The overwhelming barrier to change is the tangle of legacy systems that make it hard to aggregate and understand the current conditions of assets and their maintenance records. Too often, data remains siloed and inaccessible, floating in the realm of transactional logs and spreadsheets.

Location intelligence cuts through the complexity, providing a common language to give data a physical presence on maps. That presence promotes an understanding of the context that unites layers of other relevant information. Once disparate types of data can be visualised and analysed in relation to each other, it reveals insights that guide agile, real-time decision-making.

A smart map of all MTA assets is not restricted to two-dimensional space. Its 3D scenes contain representations of all bus stops, underground tunnels, switches, and work orders. It shows maintenance types and allows you to track progress at each location over time.

This level of visualisation also uncovers root causes of maintenance problems. It recognises, for example, the thousands of signals in the underground that serve to both keep customers safe and improve overall efficiency by keeping trains spaced correctly.

Creating a digital twin captures details about assets, components, and facilities. Location intelligence is its nervous system, sensing changes in the physical world, increasing our understanding of it, and enabling us to take systemic and collaborative action.

Surfacing data about conditions and constraints in each place along routes and tracks gives everyone in the organisation a tool to relate their work to the work of others. It compels different operational units to collect and share data, related to their areas of expertise, about each place. This data supports fact-based and evidence-based decisions that improve efficiency, safety, operations, and planning.

Organisations that adopt location and spatial analytics gain the ability to understand why things happen where they do. Through location, they can begin to detect and quantify problems and make predictions to drive performance and transformation. ▶

Powering Maintenance Intelligence

Traditionally, facility managers have relied on computer-aided design (CAD) drawings to depict building interiors and route workers to where work needs to be done. Yet these static illustrations often don't reflect current configurations. By adding geographic information system (GIS) maps, managers can strengthen the data behind building maps, keeping them fresh and relevant even in the midst of massive construction and modernisation projects. Moreover, capturing and visualising maintenance data in immersive 3D maps shows real-time information in multidimensional space.

CAD drawings are valuable within GIS, as are legacy schematic maps and other facility documentation that can be scanned and added to the database. As a modern facility management tool, GIS technology can manage different types of information and quickly produce visualisations.

More than a way of viewing the route of a single track, the GIS-based integrated transit map is a digital twin on which to visualise and analyse different types of operations information—everything from power outages to signal conditions to bus route configurations. For instance, by integrating GIS with INFOR, the transit map shows the entire track network, across all divisions, and keeps up with every maintenance action. By joining work order and asset data to the map, the user sees the location of work in the context of all other work and assets, across the entire network. Users can add all sorts of data to the map to see, for example, the locations of tracks, signals, switches vents, pumps, and power sources while preserving the same simplified view. GIS provides a centralised record of the condition and status of all assets necessary to make the overall system work smoothly.

Digital transit maps scale to the view that users need to see, whether that be the underground line, just one track, or a drill down to specific signal switches. Zooming in to a traditional CAD drawing simply magnifies the image. But map views easily respond to a simple mouse scroll that scales transit data to the view level. They can easily analyse changes and surges in demand. By centralising data and making it visual, stakeholders can be on the same page, whether in the field or in the office. Everyone gains a shared understanding of the tightly integrated component that helps travellers get where they need to go. ▶

Esri and Integration: Work Order Management Systems

Esri technology aligns with all major Enterprise Asset Management providers, including INFOR, Bentley, RedHat, Microsoft Azure, and Amazon Web Services. The result is a geospatial context and spatial analytics engine to query and understand problems. This technology integration offers seamless and dynamic access to GIS functionality that provides map-based communication and offers new insights.

GIS is designed to be integrated with other large systems to add additional details to the map—such as providing real-time bus and train locations, improving customer communications, and allowing for accurate and timely customer advisories. It provides the ability to explore a route or network to quickly display the current status of buses; trains; or a network asset such as a signal, pump, or vent. GIS can also display real-time data such as service requests and tap into sensors that monitor energy usage or send alerts of pending asset failures. This information can be cataloged and later used to perform sophisticated analytics, within the same GIS environment, to better improve the efficiency and functionality of the overall system.

Indoor maps simplify work order management. Maintenance managers receive a request or see a remotely sensed problem appearing as a red dot on the work order map. The manager clicks the dot, sees the problem and location information, and dispatches a work order to a technician.

The technician receives the work order on a smart device and sees the problem description. To accept the work order, the technician taps an icon. Back in the office, the work order status automatically changes, which is noted on the work order map as the red dot changes to yellow. Upon entering the building, the technician opens the wayfinding app and follows its route to the problem's location. To begin the repair, the technician uses a mobile survey app to confirm the problem, take photos, and add notes. When finished with the repair, the technician taps the Complete icon, sharing photos of completed work. The app instantly streams the information to the GIS database, and the map's status dot changes to green. ▶

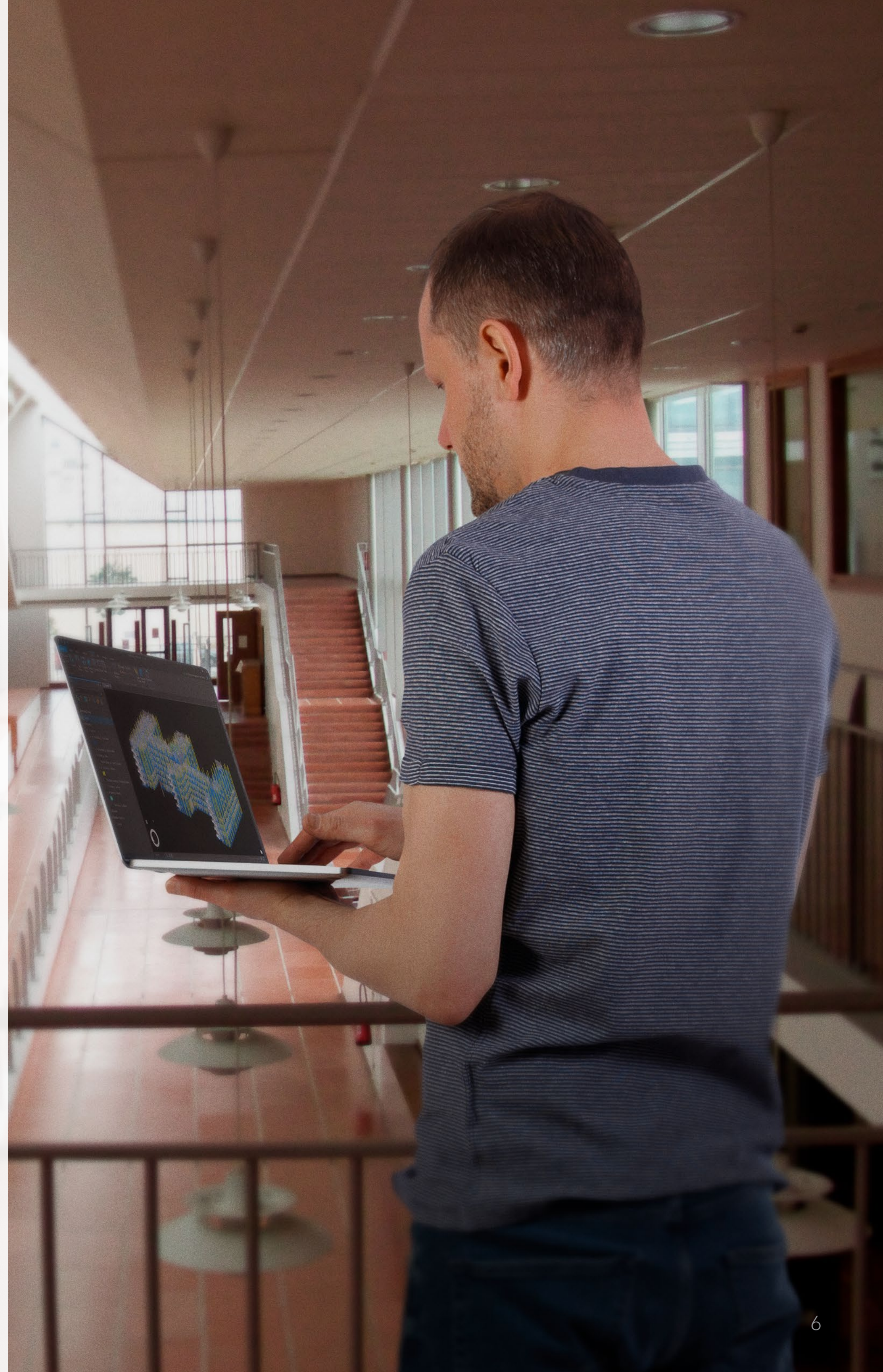
Maintenance Situational Awareness

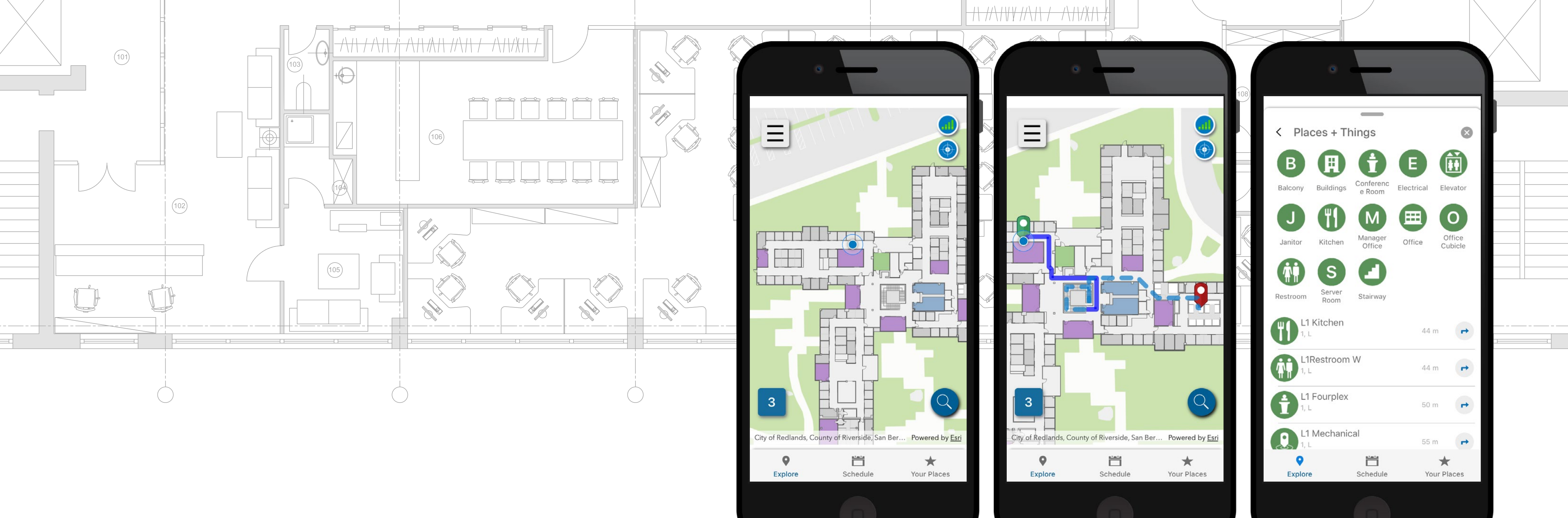
Government organisations and multinational corporations manage geographically dispersed real property portfolios. For instance, a university's property portfolio contains academic buildings, maintenance yards, residence halls, theatres, and offices. An airport's portfolio includes terminals, indoor transportation, hangars, and control towers. The MTA's trillion dollars' worth of assets is even more complex, involving different interlocking systems (e.g., buses and trains) amid a backbone of line structures. These assets are in constant motion 24 hours a day in a densely populated city that never sleeps, and they're operating in three dimensions, including underground, often inches away from critical infrastructure.

Keeping track of a wide range of property requires a powerful system to manage massive amounts of data. Real property files comprise lease and ownership information, floor plans, track schematics, operational systems documentation, energy usage, space allocation, maintenance history, and much more.

Mapping real property on a large scale reveals where and how facilities align with operational objectives. GIS indoor and underground maps show where problems exist and where action is required. Operations managers can tap on a map and bring up vital operational information about assets, vehicles, and tracks wherever they are in the world. Indoor maps scale, allowing managers to deeply drill into a track's information, see key performance indicator (KPI) metrics, and visualise relationships that help them make data-driven decisions.

Locally, track managers can run GIS modeling tools and analytics to determine whether trains are performing efficiently. Predictive models also help forecast maintenance priorities. Operators use this information to evaluate on-time performance, enhance the state of repair, respond to power outages, and enhance ridership satisfaction. ▶





Enhancing Communication and Collaboration

Large public transport and rail organisations have long used GIS technology to establish the location of assets and visualise the interplay between natural and built environments. GIS provides a real-time understanding of assets, whether moving or stationary. Building information modeling (BIM) software has helped those same organisations plan and model the construction and operations of buildings and other structures.

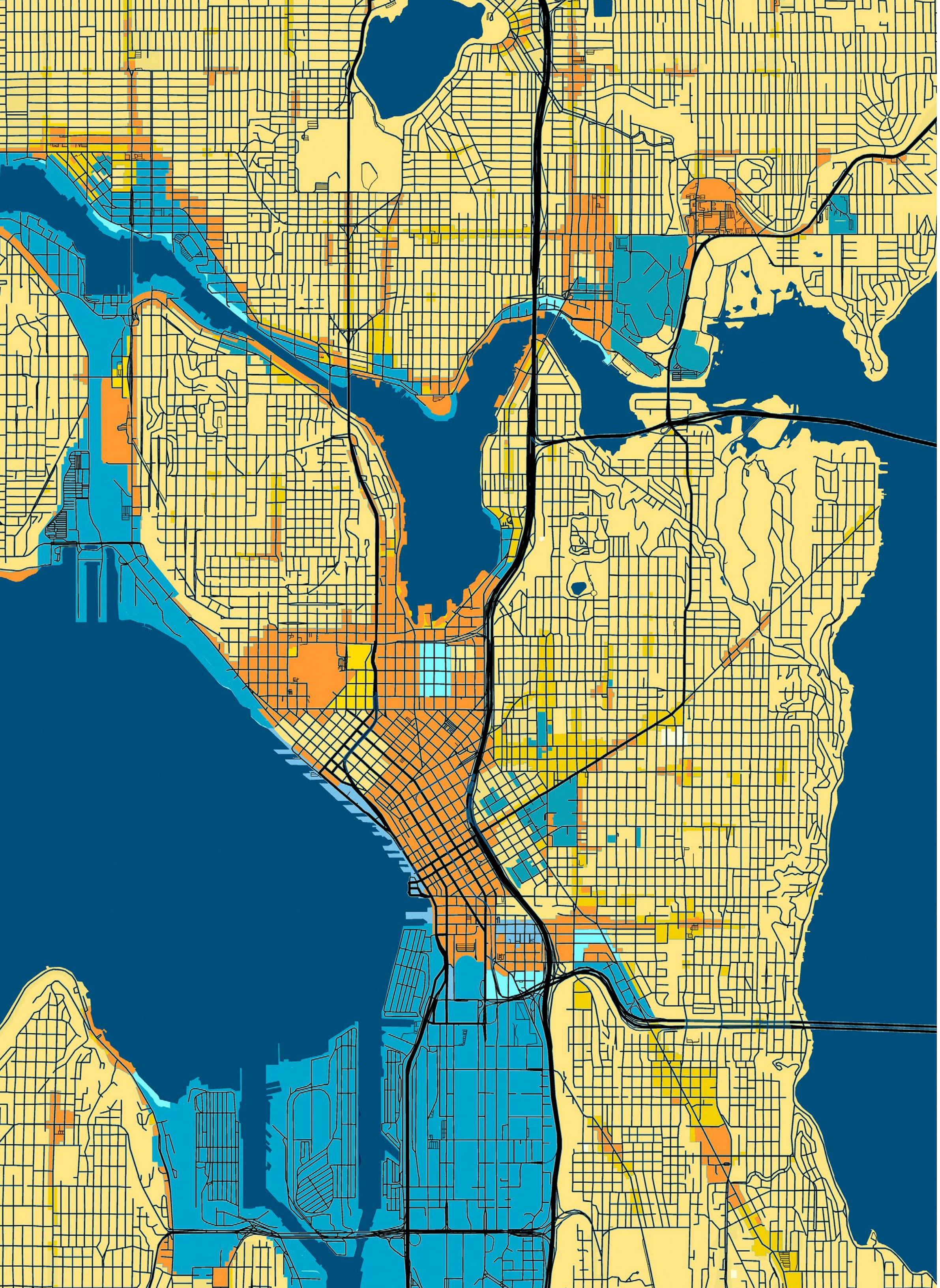
By integrating digital data from GIS and BIM, you can see the full scope of work and the interdependencies of individual steps. At the same time, you gain a level of visibility that helps control costs and improve safety, operations, and maintenance. At the executive level, an integrated GIS-BIM-asset management solution enables project leaders to visualise the evolution of a massive maintenance project across space and time.

At the project level, the combined systems make difficult tasks safer and more manageable. Together, GIS and BIM help engineers gather details about existing infrastructure, revealing the precise layout of dangers such as underground utilities. Standards can be set in a centralised fashion, and work can be planned with all safety considerations in mind.

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

In more advanced facilities, sensors collect information about people and objects in the building and transmit it to a tracking service. Upon subscribing to a location service, contractors and maintenance workers can share their current location with others who may need to find them. These sensors can also help reveal complex hidden patterns in human traffic and mobility, allowing for optimal improvements in bus route configuration and the design of stations and platforms.

The combined environments of modern GIS, BIM, and asset management in apps, desktop software, and the cloud provide an integrated and collaborative workflow. This removes silos and improves understanding of projects in context, reduces inefficiencies, and delivers more sustainable and resilient infrastructure. ▶



GIS Aids Construction Workflows

As governments and AEC firms revitalise global infrastructure and create digitally connected and smart facilities, they are turning to two technologies that have traditionally stood apart but are now coming together–GIS and BIM.

GIS technology has long helped AEC professionals establish the location of assets and visualise the interplay between natural and built environments. BIM software has helped those same professionals plan and model the construction of structures and buildings. Integrating digital data from the two systems is helping projects move faster while controlling costs and improving safety.

At the executive level, an integrated GIS-BIM solution helps project leaders visualise the evolution of massive construction and capital projects across space and time. At the project level, this capability makes perilous tasks safer and more manageable.

When digital systems such as GIS and BIM are integrated, key data flows swiftly to decision-makers. If a gas line ruptures or an emergency strikes, responders no longer have to fumble with printed maps, searching for information that is often out-of-date.

Armed with digital intelligence, AEC leaders, project managers, and city planners can manage construction projects more efficiently—and respond more effectively in times of emergency. Leaders in some of the most advanced cities in the world are using these new tools to ensure that they develop infrastructure and construction projects that meet the standards of a smart world. ■

LONDON:

Crossrail Rides in a Common Data Environment

Crossrail Ltd is building a new railway for London: the Elizabeth line. Europe's largest infrastructure project, the Elizabeth line will increase central London's rail capacity by 10 percent, decreasing journey times and adding £40.3 billion in economic benefits to the United Kingdom.

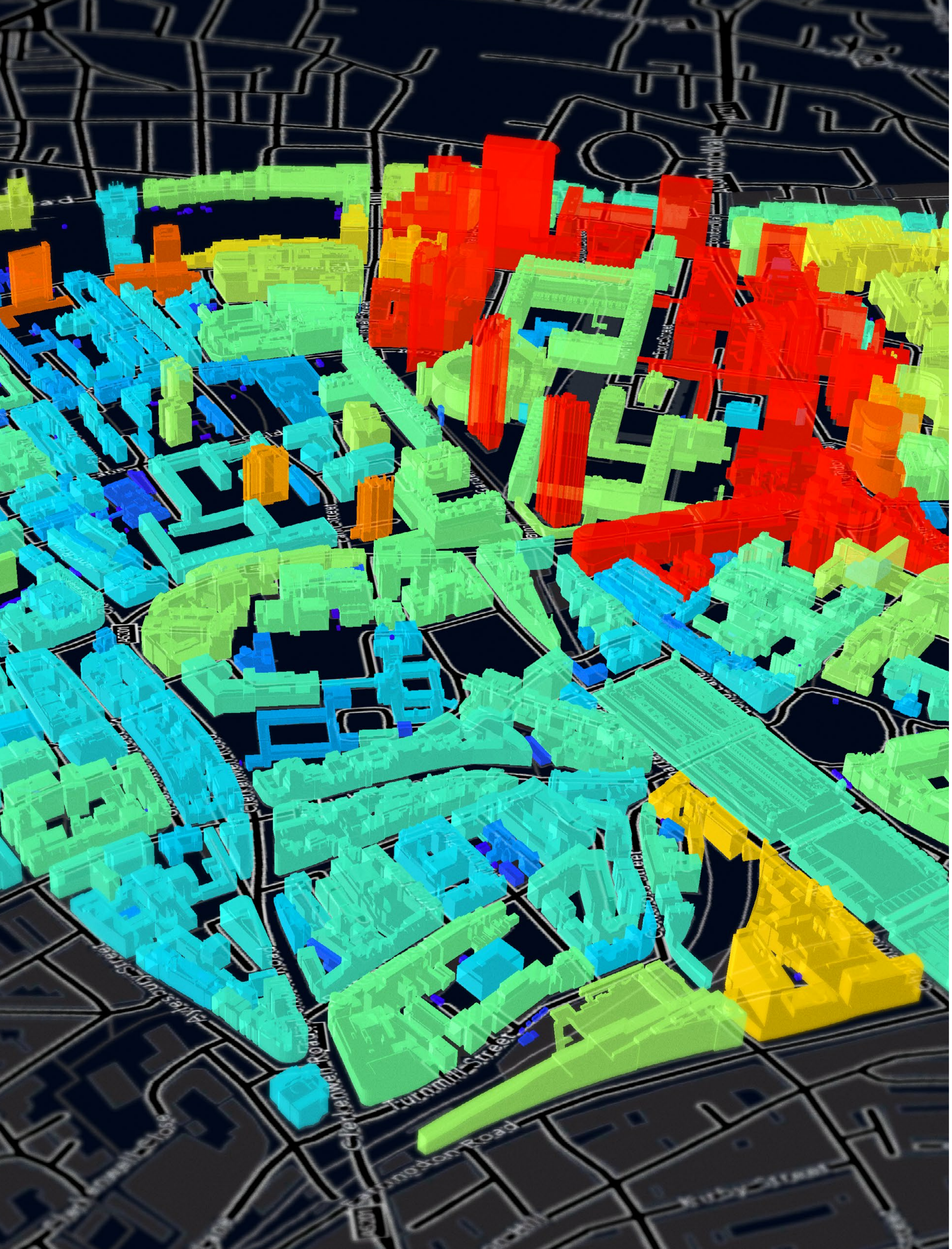
To create 10 new train stations and 80 miles of track (including 26 miles of tunnels underneath central London), Crossrail Ltd is managing 25 design contracts, 30 advanced work contracts, and over 60 logistics and main work contracts.

At that huge scale, a common data environment is essential to prevent information loss, eliminate silos, and make better decisions across the project life cycle.

All design plans incorporate 3D models, and Crossrail Ltd chose GIS to act as a bridge between CAD files and documentation. GIS will provide a complete database to hand over to Transport for London (TfL), which will operate the completed system. GIS also provides the crucial wider geographic context of each asset's location, plus a means to share and leverage rich 3D BIM data.

The integrated system has produced maps of such precision that work crews could proceed confidently even when tunneling underground with massive digging machines, where a tiny miscalculation could result in millions of dollars' worth of damage and delays. Nonetheless, a confident Crossrail team tunneled within 1½ feet (50 centimeters) of an existing rail station and never feared being off target.

The integration of GIS and BIM produces real-time snapshots of design plans and progress alongside demographics, traffic flows, or utility usage—all in the context of location. BIM supports the familiar 3D environment and key information for building and construction. GIS software manages massive data flows from sensors on essential equipment, tracks, roads, vehicles, and cash registers and across the Internet of Things. ▶



Crossrail (continued)

Because plans were digitised, citizens stayed informed. Crossrail Ltd saw an average of 250,000 visits per year to its open data portal. Online maps jump-started new residential and commercial developments along the route.

As members of the joint venture design team, Arup Atkins, approached the Crossrail project, they realised they would need a special strategy for tracking thousands of buildings while boring huge tunnels around the foundations of new and historic structures and untold miles of utility pipes and cables.

Assisted by the leading GIS software developers, the Crossrail group created an innovative combination of GIS and BIM. With GIS, they can analyse hundreds of layers of data and display the results on easy-to-understand maps showing precise locations of buildings, tracks, and utilities. With BIM, staff can add detailed 3D models of structures.

The result allowed Crossrail to centralise and integrate information from more than 100 major design and construction contracts with more than 1 million computer-aided design files. The team could then share parts of the central database through a secure, user-friendly portal with contractors and managers.

The GIS-BIM platform also produced an 80 percent increase in efficiency in some jobs related to filing data, maintaining schedules, and creating reports.

When completed, the project—plus all the knowledge accumulated during the construction phase and all the info needed to run the new rail line—can be smoothly handed off to those who will operate it. ■

LOCATION LESSONS LEARNED FROM HURRICANE SANDY:

The Need for a New Level of Preparedness

The immense damage caused by Hurricane Sandy and the historic storm surge levels that swept across New York City on Oct. 29, 2012 served as a wake-up call for cities globally about how critical infrastructure could be impacted by such an event:

The storm flooded 17 percent of the city's land mass and caused $19 billion worth of damages to public and private property.

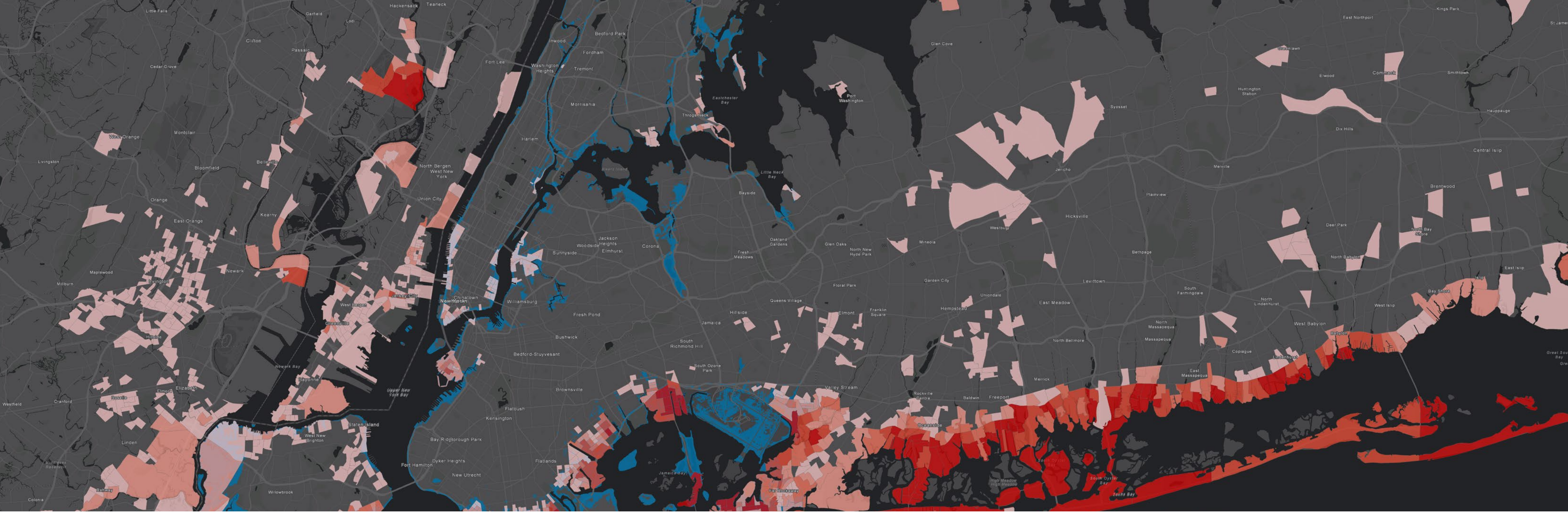
The Con Edison electric substation serving lower Manhattan, including Wall Street, was low to the water line and lacked a retaining wall. When it was swamped by the surge, transformers exploded, and it took five days to return power to the country's financial centre.

The five basement floors of the New York University Medical Center also flooded, closing the hospital and necessitating the evacuation of patients in the middle of the hurricane. The bill for this damage alone totaled more than $1 billion.

Despite valiant efforts to close operations, fortify tracks, and move equipment to higher ground, the subway system was hard hit. Lower Manhattan train stations at Whitehall and Canal Street were devastated by the rising water, and seven subway tunnels connecting Manhattan to Brooklyn and Queens were flooded.

In the aftermath of the storm, a map helped city residents see the real-time return of service. The quick communication helped keep citizens and transit workers safe and helped New Yorkers rebound quickly from one of the largest disasters it has ever faced.

What we learned is that infrastructure wasn't resilient enough to meet the new normal of devastating storms. We knew how high a storm surge could reach. What we didn't have was an understanding of all of the critical infrastructure that would be affected. ▶



Hurricane Sandy (continued)

GIS contains the data and tools to understand and assess such threats. Foundational GIS data includes street maps, parcels, building footprints, and information on city assets and infrastructure. It also provides the means to model scenarios, such as the actual or potential extent of a storm surge, in order to make plans to take mitigative actions.

3D adds another layer of value to data. Being able to see the location of utilities in 2D is well established. The 'call before you dig' service locates lines and spray-paints markings on the street. Adding 3D to the equation tells crews that are excavating that the water line is below the electric line, which is below the sewer line. Knowing where it is in 3D makes that operation a lot more efficient.

A detailed 3D model captures location, context and relationships. The model conveys where underground gas lines, electric lines, water lines, steam lines and subway lines are in proximity to each other. Including characteristics such as age and materials gives maintenance crews an ability to prioritise what needs to be repaired or replaced.

Many cities around the world have begun modeling the entire built environment (above- and underground) and the natural infrastructure of a region (forests, wetlands, waterways, etc.) to create a digital twin as a backbone for better city management.

Auckland has a connected model that aligns buildings with water and sewer systems as part of their smart city vision. London, Helsinki, Zurich, Melbourne, Singapore, Hong Kong, and others have various levels of integrated city models under way.

Sandy served as a call to action to revitalise and reimagine NYC's coastlines to be more sustainable and more resilient to these threats. Advancement in technology and a growing movement on city-scale modeling hold great promise to aid resilience and form the backbone of a smart city plan. GIS has a history of shining during a crisis, and with data-driven workflows and analytics, it creates the kind of awareness that can reduce suffering. ■

THE NETHERLANDS:

Port of Rotterdam Sinks Separate Asset Information Silos

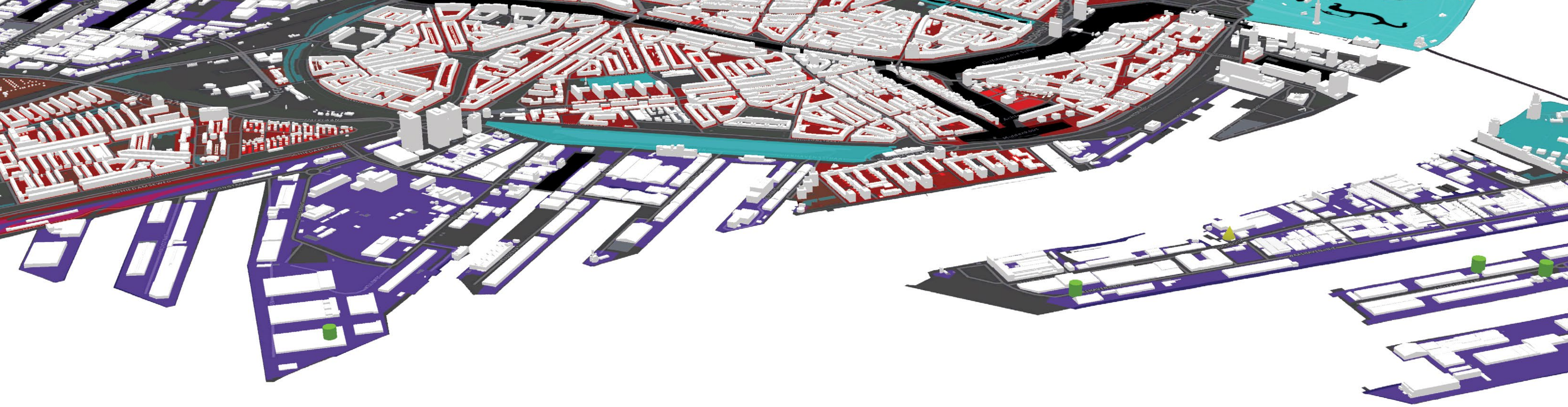
In 2013, the Port of Rotterdam set a goal to grow from 400 million tons of cargo per year to 750 million by 2030, vowing to become faster, smarter, and more sustainable. To achieve this audacious goal, the port was forced to take stock of its operations, including its strengths and weaknesses.

Much like New York City's mass transit system—with its 1.7 billion annual subway riders, 700 million bus riders, and millions of commuter train passengers—the Port of Rotterdam is a complex organism that operates around the clock, 365 days a year. In a typical year, 35,000 ships (nearly 100 a day) visit, carrying 400 million tons of cargo; 80,000 barges enter the port; 7.5 million trucks traverse its roadways (that's 25,000 trucks every day); and 80,000 employees come and go for work.

But from a business process standpoint, the Port of Rotterdam was a tangle of disjointed legacy systems that put different employees and assets into silos. Port leadership began to examine what needed to change. "We had to let go of everything," said Erwin Rademaker, port manager. "We went back to the start and asked ourselves basic questions. What are we? What is a port?"

Ultimately, the solution was clear. "The only thing that is left for us to do is to improve or to optimise what we have," explained Rademaker. But the billion-dollar question remained—how?

At the time, port developers, business managers, project managers, asset managers, environmental advisors, port harbor operators, financial analysts, and many others, made the daily decisions that kept the port running. Each group used its own system for data collection and reports, and making matters even more confusing, individual groups used different definitions for terms used across the port. ▶



Rotterdam (continued)

The port, its leadership realised, needed one centralised authoritative source of information for all users and assets—a single point of entry that would allow anyone, anywhere, to quickly access the data they needed to make smart decisions and perform their jobs more efficiently.

"We needed another modality in our port, and that is information. Because nothing in the port moves without information. Everything in the port, from the largest berth to the smallest lock and key, is connected by information," said Rademaker.

After researching best-in-class information systems, the Port of Rotterdam set its sights on creating a solution based on GIS technology. At its core, the solution is a beautifully simple map of the port. Underneath the skin of the map lie terabytes of big data—all accessible within three mouse clicks, and all with connections to SAP, Microsoft Office, and a document management system.

The port recognised that there are three distinct spatial components to the port and its users, and that each drives revenue generation in a different manner: the land component is used by terminals and infrastructure; the water component is used for transportation; and the interface between land and water is used for the mooring of ships. With those simple divisions, it was straightforward to assign existing layers of data to the 10 core objects that comprise the new port data system.

During implementation of the new GIS remedy, port leaders managed to phase out 49 other systems with relatively little disruption. Employees participated in the data migration, making the process one of active learning and training. And teenage children of employees tested the new interface, making sure it was truly user-friendly.

Today, more than 1,000 digital maps are created each day to guide operations and decision-making. In fact, all Port of Rotterdam data is presented visually. Any employee can pull up a map on a computer or mobile device, navigate to an area of the port, and click for more information. For instance, clicking on a wharf shows maintenance information, current contracts, ship movement data, and more.

Since implementing the new system, the port has seen an increase in throughput to 461 million tons—a 15 percent increase since 2013 and a significant step toward its 2030 goal.

Aside from financial goals, the port sees its new GIS-based approach as a way to become a world-class port. "Instead of being the biggest port in the world, which we were for decades," said Rademaker, "we want to be the best port in the world. That means the most responsive to our customer needs." ■

UK:

High Speed 2 Rail Project Breaks Barriers before Breaking Ground

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 miles per hour. The line, High Speed Two (HS2), builds on 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.

GIS data specialist George Floros works with the Skanska, Costain, and STRABAG Joint (SCS JV), the group responsible for the London portion of HS2 construction. In building the rail line from the centre of London to northern parts of the city, Floros notes that, as with the New York City metro area, the "densely populated environment makes BIM and GIS integration critical."

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. ▶

High Speed 2 (continued)

Floros and his colleagues use GIS to visualise details about the location of above- and belowground networks and to analyse 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 eliminate any weak points."

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 standardised 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 visualisation look pretty," Floros said. "The key is to focus on what questions added dimensions address. The purpose of the shared data platform is analysis." ■

AMSTERDAM:

Digital Twin Helps One of Europe's Biggest Airports Optimise Operations

Schiphol Airport in Amsterdam is the world's second largest airport in terms of hub connectivity, and it's the 11th busiest overall. It provides a major gateway for passengers and cargo to the Netherlands and the rest of Europe.

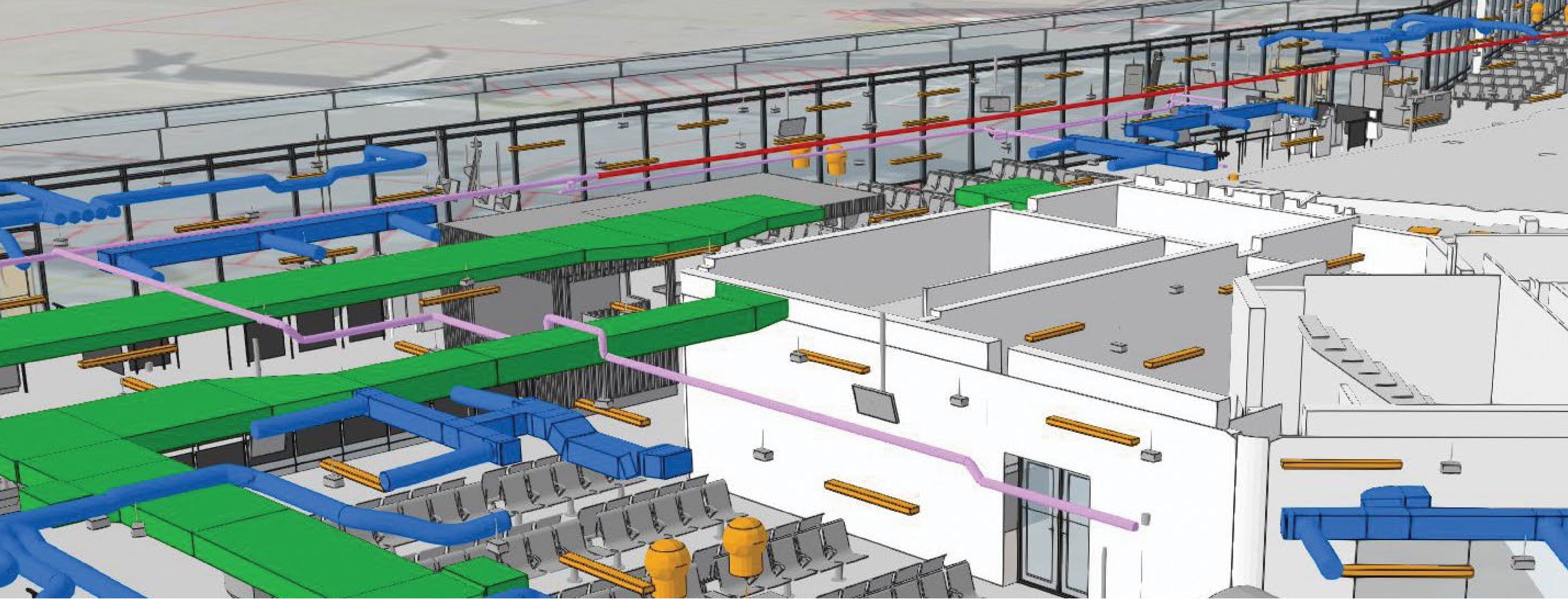
In 2017, Schiphol Airport began a capital improvement program, scheduled to last for several years, that involves a major renovation of existing facilities and the construction of new ones. To take advantage of the numerous digital assets created for the capital improvement program, the airport built a digital twin.

"The airport's digital asset twin provides the opportunity to run simulations on potential operational failures throughout the entire complex, which saves us both time and money," said Kees van 't Hoog, head of the Development Operations team at Schiphol Airport.

This digital twin, known as the Common Data Environment (CDE), organises data from many sources: BIM, GIS, and data collected in real time on project changes and incidents as well as financial information, documents, and project portfolios.

The data from remote sensors feed the CDE to provide predictive maintenance. Within the 7,000-acre complex, the airport tracks and maintains more than 80,000 assets—both indoor and outdoor—ranging from networks, runways, and lighting systems to information booths and fire extinguishers.

Schiphol's contractors provide construction data in BIM software. Every detail of a building—geometric and nongeometric design elements as well as construction information—is captured in the building information model. This information-rich model is used for analyzing design options and creating visualisations. ▶



Schiphol (continued)

The 3D Schiphol Urban View is a web scene that gives managers, technicians, contractors, and other stakeholders a detailed view of the current status of construction. The web scene also functions as a dashboard for the asset management process. As part of Schiphol's CDE, it can use attribute data from other systems and display real-time asset data for remote inspections.

Automated passenger and freight systems at the airport—such as escalators, conveyor belts, and ticketing machines—are monitored by an asset control signaling and monitoring (ACSM) implementation within Schiphol's supervisory control and data acquisition (SCADA) system.

Together, these systems continually monitor and check the status of the multitude of servomotors, circuit boards, and mechanical devices that comprise these systems. Schiphol uses IBM Maximo asset management software for asset registration and maintenance records.

"The ACSM lets us monitor and manage all of the assets comprising these systems in real time from a dashboard," said van 't Hoog. "So if one of the components that make up these systems—such as a belt or motor—is not running correctly, we can turn the equipment off, automatically produce a work order, and assign a maintenance crew to immediately repair it."

Schiphol has introduced Veovo's BlipTrack technology as its indoor traffic monitoring system. BlipTrack sensors detect a passenger's wireless device, and its unique ID is time-stamped and encrypted. As the device passes by multiple sensors, the system measures travel times and movement patterns. It provides both real-time and historic information about queue times, occupancy numbers, and flow patterns to airport management, which helps staff maintain a safe and secure environment. ■

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Since 1969, Esri has helped customers unlock the full potential of data to improve operational and business results. Today, Esri software is deployed in more than 350,000 organizations including the world's largest cities, most national governments, 75 percent of Fortune 500 companies, and over 1 in 5 FTSE 100 companies using Esri technology, and more than 4,000 UK colleges and universities. Esri engineers the most advanced solutions for digital transformation, the Internet of Things (IoT), and location analytics to inform the most authoritative maps in the world.

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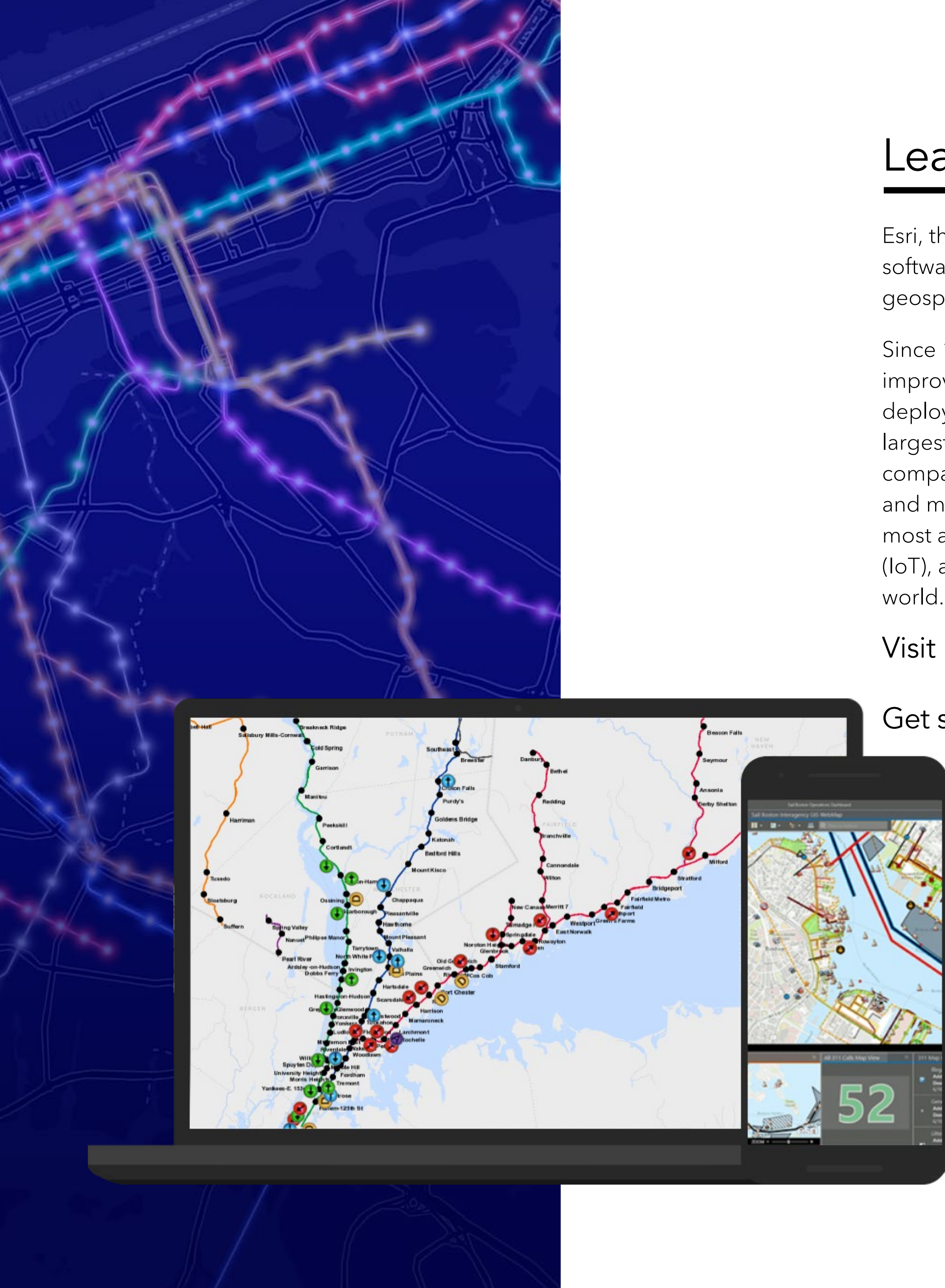

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