the science of where

Building Smart Infrastructure in a Digital Age: Global Innovators

HOW **GLOBAL INNOVATORS** ARE DRIVING CHANGE

IN a prescient 2013 article, Canada-based consultant Geoff Zeiss anticipated a global surge of critical infrastructure investment. An infusion of private funding, he said, was already driving technological innovation into the industry, as private companies sought greater productivity and higher return on investment.

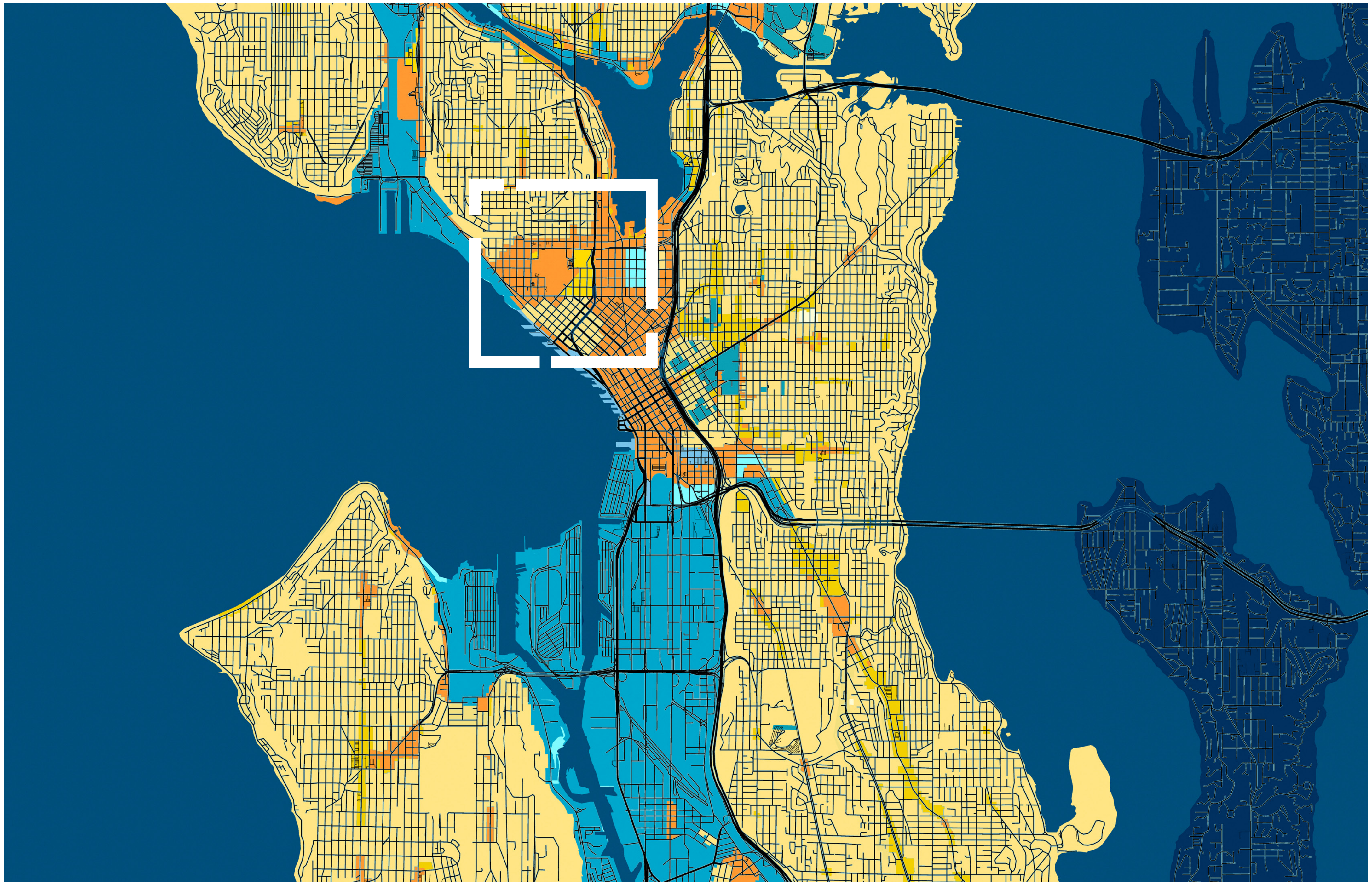
He wrote at the time: "Converged solutions using existing BIM [building information modeling], geospatial, and 3D visualization technology are being applied to intelligently model urban infrastructure and entire urban environments ranging from neighborhoods to a medium-sized city."

The nascent digital integration that Zeiss observed in 2013 is now spreading through the architecture, engineering, and construction (AEC) industry, helping to create smarter and safer cities.

Around the globe, avoidable disasters and a constrained flow of commerce have inspired many countries to boost spending. According to McKinsey Global Institute, global infrastructure investment rose from 2013 to 2015. In the United States, the White House called for a $1.5 trillion investment in infrastructure renewal. Under the plan, $200 billion would come from federal spending; the rest would flow from states and private investors. Whether that specific plan or another one wins out, private dollars will likely play a prominent role.

To maintain its rate of economic growth, the United States will need to spend $150 billion on infrastructure renewal each year until 2030, according to McKinsey. Few experts dispute the correlation. After years of underinvestment, maintenance on the country's roads, bridges, rail, energy, and water infrastructure is dangerously out-of-date, stunting the flow of commerce and even imperiling lives. ▸

DIGITAL TRANSFORMATION IS SPREADING THROUGH THE ARCHITECTURE, ENGINEERING, AND CONSTRUCTION INDUSTRY, WITH GREATER EFFICIENCY AND SAFETY ITS BY-PRODUCTS.



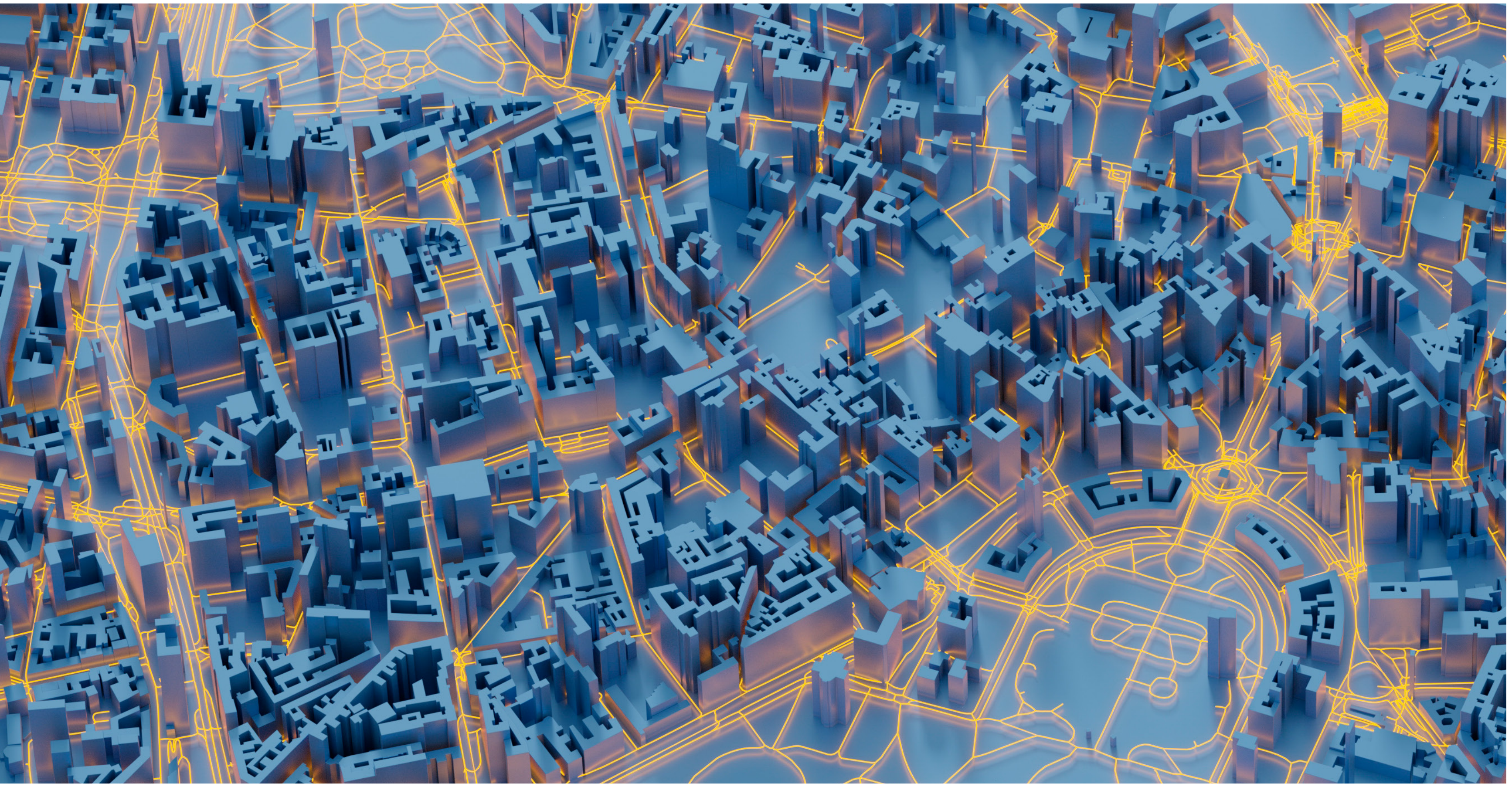
An Industry's Digital Transformation

One underappreciated benefit of digital transformation is the ability to tie together data, combining information that would otherwise languish in isolation. Combined datasets often yield insight that directly impacts the safety and integrity of critical infrastructure projects.

In its guiding principles, the American Society of Civil Engineers says that infrastructure projects "must be developed using a systems approach with an understanding of all connections, interactions, and interdependencies between system components."

That integrated approach will become increasingly important as governments and AEC firms revitalize global infrastructure and create tomorrow's digitally connected smart cities and buildings. ▸

DIGITAL TRANSFORMATION IS WIPING AWAY THE INEFFICIENCIES OF THE PAST.



Fusion of Two Technologies

As Zeiss noted back in 2013, two technologies that have traditionally stood apart are coming together to support this work. Geographic information system (GIS) technology has long helped AEC professionals establish the location of assets and visualize the interplay between natural and built environments. BIM software has helped those same professionals plan and model the construction of buildings and other structures.

Integrating digital data from the two systems is helping projects move faster while controlling costs and improving safety. Take the recent construction of a series of rail stations in the busy heart of London. At the executive level, an integrated GIS-BIM solution helped project leaders visualize the evolution of a massive infrastructure project across space (130 kilometers of rail line) and time (a 120-year operating life cycle).

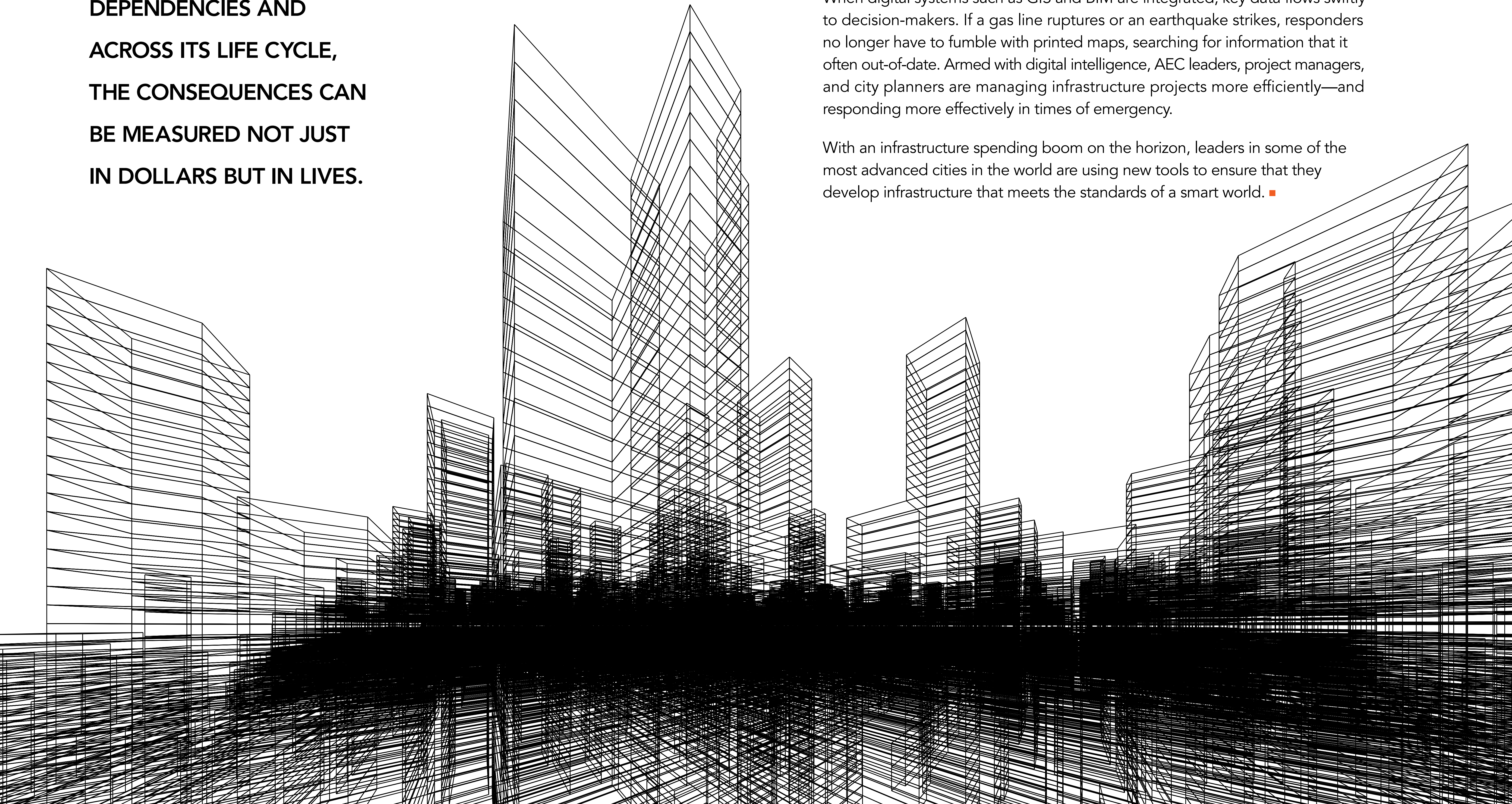
At the project level, the combined systems made perilous tasks safer and more manageable. In one instance, the technology revealed the precise layout of underground utilities, so a tunnel boring machine could operate safely just 50 centimeters below an active subway platform. ▸

WHEN PLANNERS LACK A VIEW OF ALL OF A PROJECT’S DEPENDENCIES AND ACROSS ITS LIFE CYCLE, THE CONSEQUENCES CAN BE MEASURED NOT JUST IN DOLLARS BUT IN LIVES.

Swift and Safe

When digital systems such as GIS and BIM are integrated, key data flows swiftly to decision-makers. If a gas line ruptures or an earthquake strikes, responders no longer have to fumble with printed maps, searching for information that it often out-of-date. Armed with digital intelligence, AEC leaders, project managers, and city planners are managing infrastructure projects more efficiently—and responding more effectively in times of emergency.

With an infrastructure spending boom on the horizon, leaders in some of the most advanced cities in the world are using new tools to ensure that they develop infrastructure that meets the standards of a smart world. ■



MANAGING CRITICAL INFRASTRUCTURE IN A GLOBAL CITY

To accommodate population growth, London thinks large scale and long term.

London, expected to add nearly two million residents by 2041, shares the challenge global cities face: to support accelerating urbanization and demographic change.

London's vision is to integrate operations and revolutionize how it plans, designs, and manages critical infrastructure to support a rapidly expanding population. To achieve the ambitious plans laid out by mayor Sadiq Khan in his road map Smarter London Together, organizations across London are embracing digital transformation and sharing information to realize cost savings, create efficiencies, and improve quality of life.

London was the first to introduce contactless payment for public transportation—a practice emulated by the world's leading cities. Now, London is innovating through data sharing and a modern geographic information system (GIS). Location data serves as the source of truth and an information access point for planners; stakeholders; architecture, engineering, and construction (AEC) professionals; third parties; and citizens to collaborate, plan, and understand projects. Here are three examples of GIS in action in a city that aspires to be the smartest in the world. ▸

The Crossrail Project

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 USD$54.8 billion in wider 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 building information modeling (BIM) data.

Confident in the accuracy of the location data from its BIM/GIS integration, Crossrail Ltd tunneled within 50 centimeters of an existing station without needing to close it.

Because plans were digitized, 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. ▸

Transport for London

Responsible for most transportation infrastructure across the capital, Transport for London manages roads, tunnels, bridges, pedestrian areas, and bicycle paths. TfL is a data-rich organization, but officials found they weren't using data to its full potential. So, they created a GIS-based City Planning tool to make that data available to the entire organization, giving employees access to a single source of integrated information about all transport projects and potential schemes. The tool brings together information that would traditionally be held in different systems and departments.

Mayor Khan's Healthy Streets for Londoners initiative, part of his larger Mayor's Transport Strategy, set an ambitious goal: 80 percent of journeys will be made by walking, cycling, or public transport by 2041. Objectives include reducing car usage, cutting air pollution, and improving the health of residents by encouraging more walking and cycling. TfL decision-makers use the City Planning tool to translate those goals into action. Comparing neighborhoods on a map reveals how they score on sustainability, safety, and other metrics, informing where and how funds should be invested. ▸

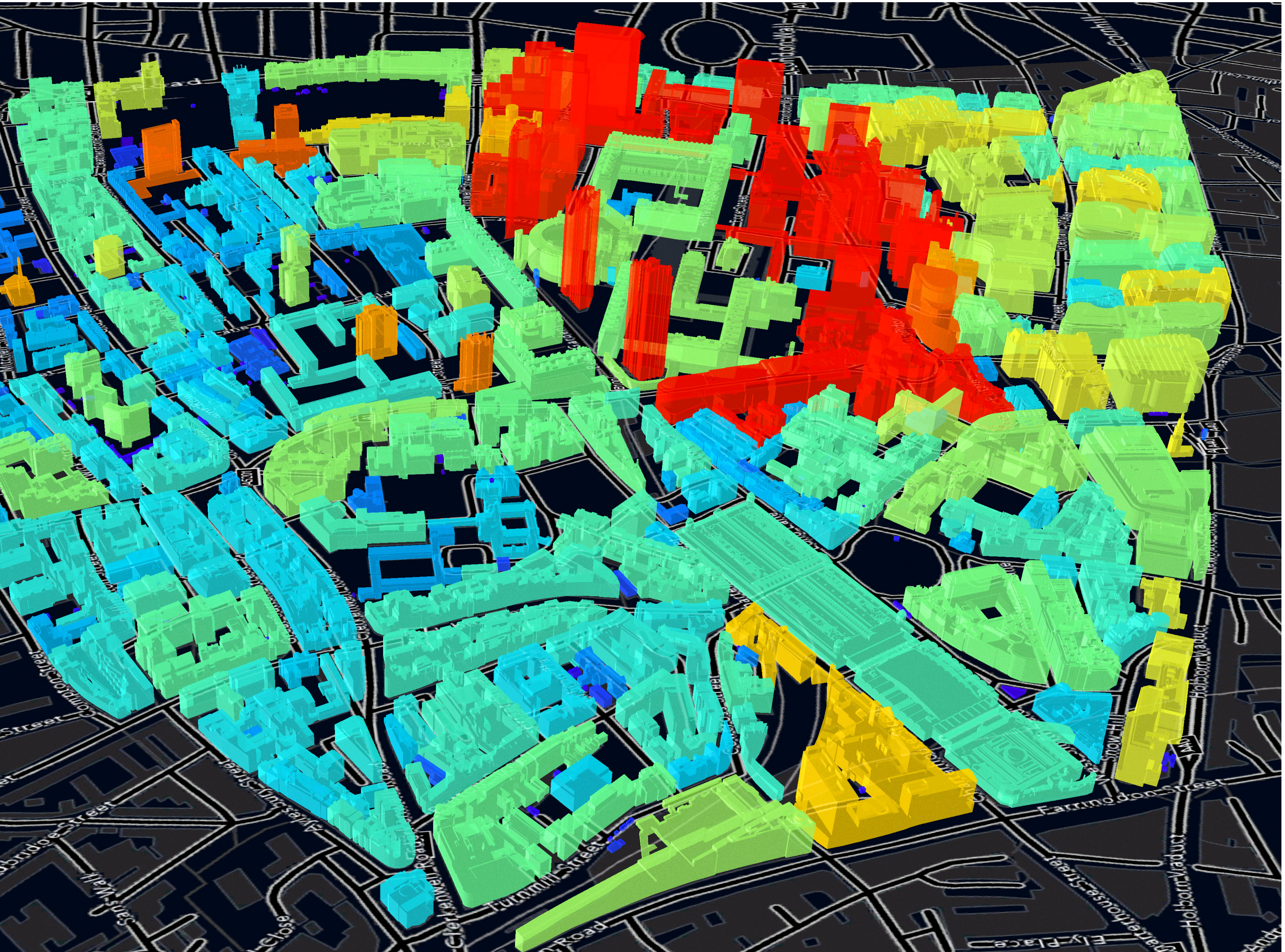
Greater London Authority

To stay competitive and serve the public, the city's leaders know the growing population will require additional infrastructure. The city will need sustainable transportation, water, energy, connectivity, and housing, and it will need these to be in the right place at the right time.

To realize that ambition, the Greater London Authority (GLA) is bringing coordination into London's project pipeline planning out to 2050.

GLA's Infrastructure Mapping Application uses GIS to represent infrastructure, development, and future investment projects, showing where they are located and what their status is. It is a web tool that brings together data on everything from new housing and schools to transportation services like the Elizabeth line and commercial developments from AEC firms, showing projects alongside population growth data and existing capacity information. Users can easily see planned infrastructure and development to help them identify opportunities for coordination and evaluate where additional infrastructure investment is needed.

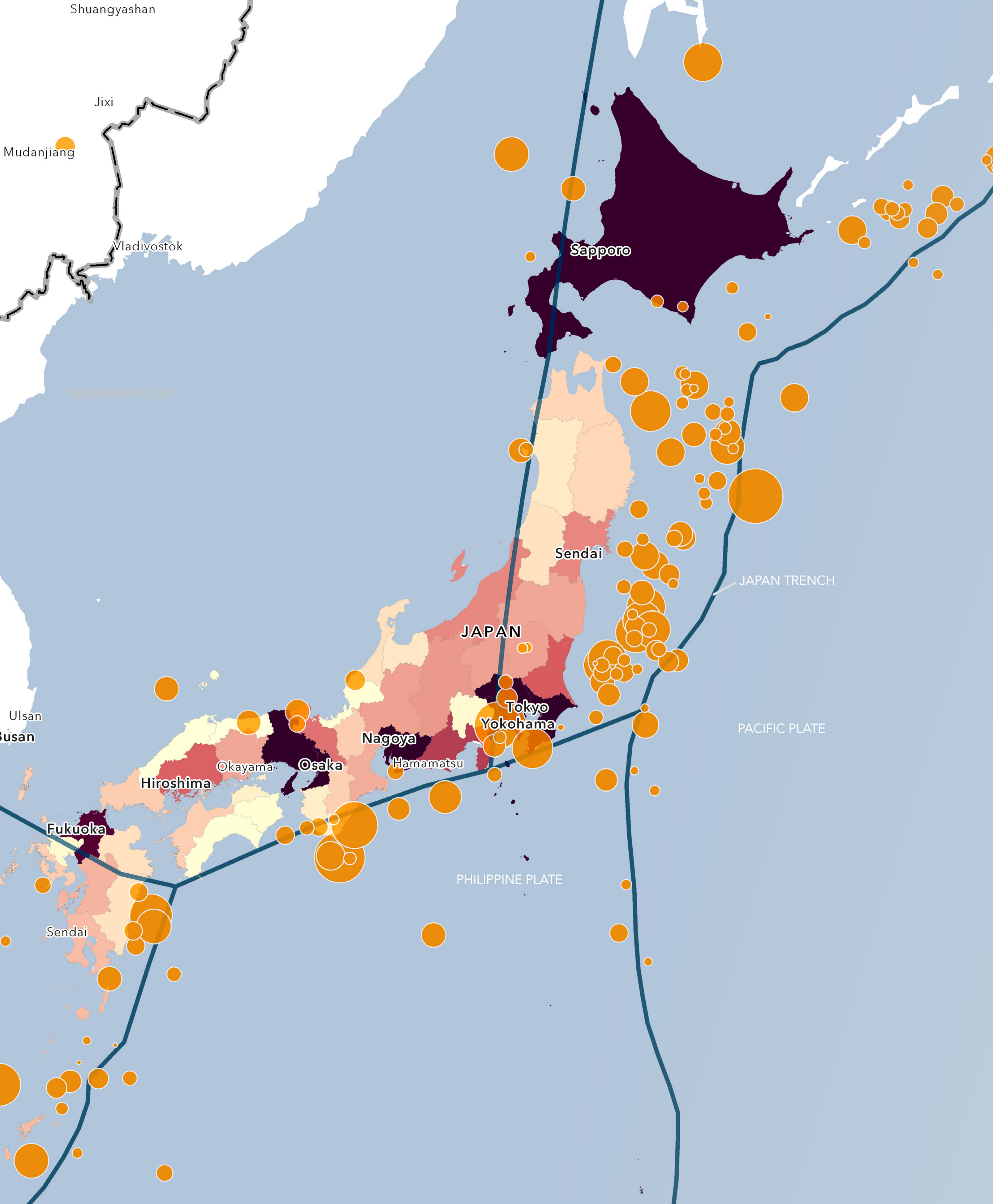
GLA is also investigating the potential for 3D modeling to support this work and improve the public's interaction with the planning system. ▸



Mapping a City's Future

The cost of massive infrastructure improvement in a global city is enormous. But sharing information through GIS creates opportunities for London to improve efficiencies and reduce costs.

By integrating disparate datasets and modeling progress over time, GIS is providing a framework to visualize and execute an entire city's digital transformation at scale. ■



JAPAN SENSES TO WARN CITIZENS OF SHAKES AND SLIDES

Sensor inputs get mapped and shared to alert the country about hazards.

"There is a 70 percent chance of an earthquake hitting directly beneath the Tokyo metropolitan area within the next 30 years," warned Haruo Hayashi, president of the National Research Institute for Earth Science and Disaster Resilience (NIED) at a 2017 gathering of scientists.

Japan sits on the boundary of multiple tectonic plates that cause extreme crustal instability. The Philippine Sea plate and the Pacific plate are sliding under the Eurasian and the North American plates, triggering as many as 1,500 earthquakes a year.

To deal with the instability, Japan has pioneered a number of monitoring and early warning systems to detect and alert people about impending disasters. NIED develops, implements, and maintains many of these sensing systems as well as the geographic information system (GIS) that processes incoming information. The GIS takes in sensor data and displays it on interactive maps and dashboards that communicate the location and severity of quakes to the public.

Extreme events, like the magnitude 9.0 Great East Japan Earthquake that hit the country in March 2011, occur rarely but have lasting and far-ranging impacts felt around the world. The triple tragedy of the earthquake, tsunami, and Fukushima nuclear disaster is hard to fathom. An earthquake under Tokyo would be far worse.

The early warning system, provided by the Monitoring of Waves on Land and Seafloor (MOWLAS) earthquake monitoring network, includes 800 highly sensitive seismographs, 70 broadband seismographs, and 1,000 strong motion seismographs across 1,900 locations on land as well as 200 locations at sea.

"The monitoring network located at sea will contribute to the early detection of the Great West Japan Earthquake," Hayashi said. "The new system has detected earthquakes 30 seconds earlier, and tsunami warnings have gone out 20 minutes before the prior system." ▸

Rain, Snow, and Slides

Japan's world-leading seismic sensing network has fostered the creation of complementary sensing networks for additional disaster types.

Landslides are a frequent hazard in Japan, given steep slopes and unstable soils. The Extended Radar Information Network (XRAIN) uses radar to detect and report the intensity of rainfall and to calculate the water content in soil. A model combines terrain and soil strength to indicate the degree of landslide danger during heavy rains. The hazard model and sensor readings feed into GIS, aligning roads and transport networks to relay transportation risks to maintenance crews and the public.

Heavy snow and avalanches also pose risks to public health and mobility. The Snow Disaster Forecasting System (SDFS) uses field observations and laboratory experiments to aid winter weather forecasting. With a combination of sensing and modeling, SDFS has the capability to alert drivers about low visibility due to blowing snow, convey the condition of snowpack on roads, forecast snow accumulation, and predict avalanche potential. The system has helped to improve forecasting, reducing the traditional 24-hour forecast to 12 hours and even 6 hours in some locations.

These two systems have helped to decrease the impact of wet and wintry weather that cause transportation delays on both roads and railways. ▸

Estimating Damage

A next generation seismic sensing system, the Japan Real-time Information System for Earthquake (J-RISQ), was recently launched. J-RISQ speeds the delivery of sensor data and provides an overall assessment of disaster severity with estimates of damage. It brings together ground motion data (collected over 20 years) that is related to the material properties of buildings and the population exposed to the tremor in order to quickly estimate the impact.

"When the Kumamoto Earthquake struck late at night on April 14, 2016, the real-time building damage estimate allowed us to quickly grasp the damage," Hayashi said. "J-RISQ captured the data correctly and calculated the damage immediately to be shared with the prefectural government, the medical assistance teams, and other disaster response organizations."

Since 2017, Japan has had the capacity to integrate inputs into one system to provide a common operational picture for large-scale disasters. The Shared Information Platform for Disaster Management (SIP4D) applies the latest science and technology for real-time response and improves collaboration and sharing between ministries and local governments.

The SIP4D system is part of a larger societal aim across Japan for Society 5.0. This next phase of human development analyzes the big data collected by the sensors of the Internet of Things with the assistance of artificial intelligence to bring new value to industry and society. Japan looks to this new era to better balance economic development while helping to solve social issues.

Disaster prevention and response are a key focus area of Society 5.0 capabilities—to provide safe evacuations, prompt rescue, and optimal delivery of supplies to impacted areas in order to reduce damages and achieve quick recovery. ■

OPTIMIZING LAND USE TO PROVIDE FOR FUTURE NEEDS

Singapore Uses Its Detailed Digital Twin to Make the Most of Every Square Meter

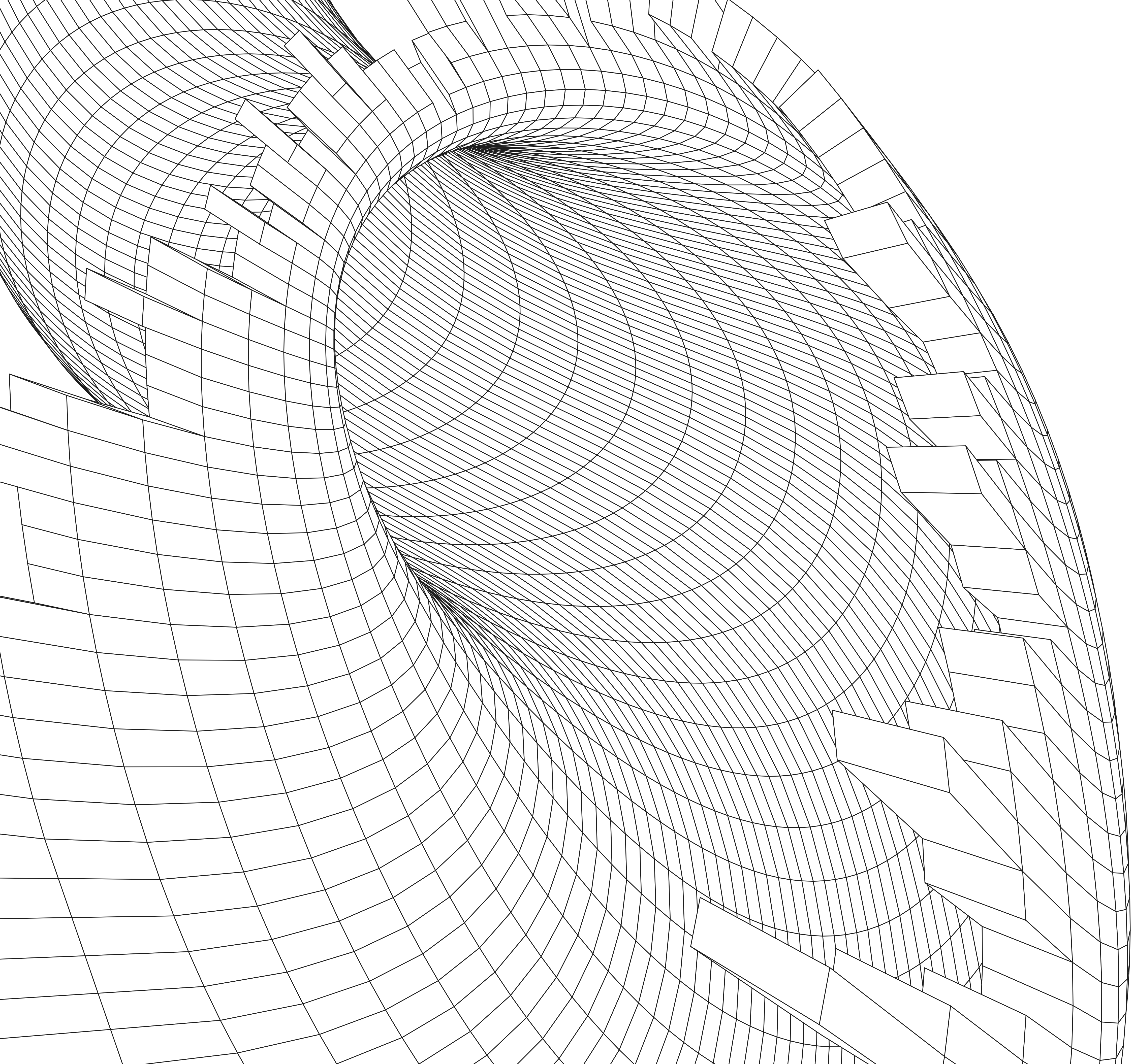
With a size of 722 square kilometers (279 square miles) and a growing population that stands at 5.5 million residents, the island city-state of Singapore needs to make use of all available space. The country's meteoric rise from a third world nation to a first world country has meant that economic growth has far outpaced land growth. As a result, Singapore has been forced to get creative in making the most of its limited resources and land holdings.

Since its independence, Singapore has rallied around long-term plans to chart housing, job development, and infrastructure investments. These plans have focused on maintaining green spaces, recycling, and adapting to changing conditions. The recently added supertrees have become iconic structures that symbolize this green country while increasing shade and adding oxygen. ▸

Singapore's integrated map system, called OneMap, informs development plans and daily government operations. Singapore Land Authority creates and manages this centralized mapping platform using geographic information system (GIS) technology. The platform acts as a point of truth about what is where in the country, delivering location-as-a-service data to a large number of purpose-built government and citizen-oriented applications. A recently released mobile app for citizens delivers live traffic feeds and routing, including highlighting walking routes that are sheltered from frequent rains.

The country's geospatial data contained in OneMap provides a pillar to Singapore's Smart Nation strategy.

The Virtual Singapore effort marks an important marriage of GIS and building information modeling (BIM) data, integrating planning and construction documents within the broader context of the country. The Virtual Singapore project is progressing, with pilot tests to see how microwaves travel through high-density areas to detect dark spots in cellular network coverage, and to model natural phenomena such as sea level rise and flash floods. ▸



Planning Underground

Singapore's leaders are now in the process of expanding their understanding of underground space optimization. They recently commissioned an underground benchmarking study that compares the city's use of underground space to that of other cities. Singapore leads all other cities for density of underground rail but lags behind other cities in the use of underground caverns.

The country successfully converted rock caverns underneath the island of Jurong, which was built with reclaimed ocean sand. The caverns opened for business in 2014 and now hold 126 million gallons of crude oil. The government is currently looking at plans for underground utility plants, observing the example of Helsinki, Hong Kong, and Seoul as well as following Helsinki's lead on underground data centers.

The country has now focused its planning efforts on the creation of an underground master plan. Underground projects include extensive subway expansions, with both the North-South Corridor and the Cross Island Line slated for completion by 2030, and a deep tunnel sewage system scheduled to be finished in 2024. Materials from tunneling work will go directly into land reclamation, with another 10 percent growth in land mass planned by 2030. ■

THE BENEFITS OF DIGITAL SUBMISSIONS:

TIME, MONEY, ENVIRONMENT

When it comes to developing and improving infrastructure for communities around the world, geographic information system (GIS) technology and building information modeling (BIM), together, are helping to bridge the gap between traditional planning and design.

In particular, close integration of GIS and BIM is allowing communities to optimize designs, accelerate project approvals, cut cost, and create resilient infrastructure.

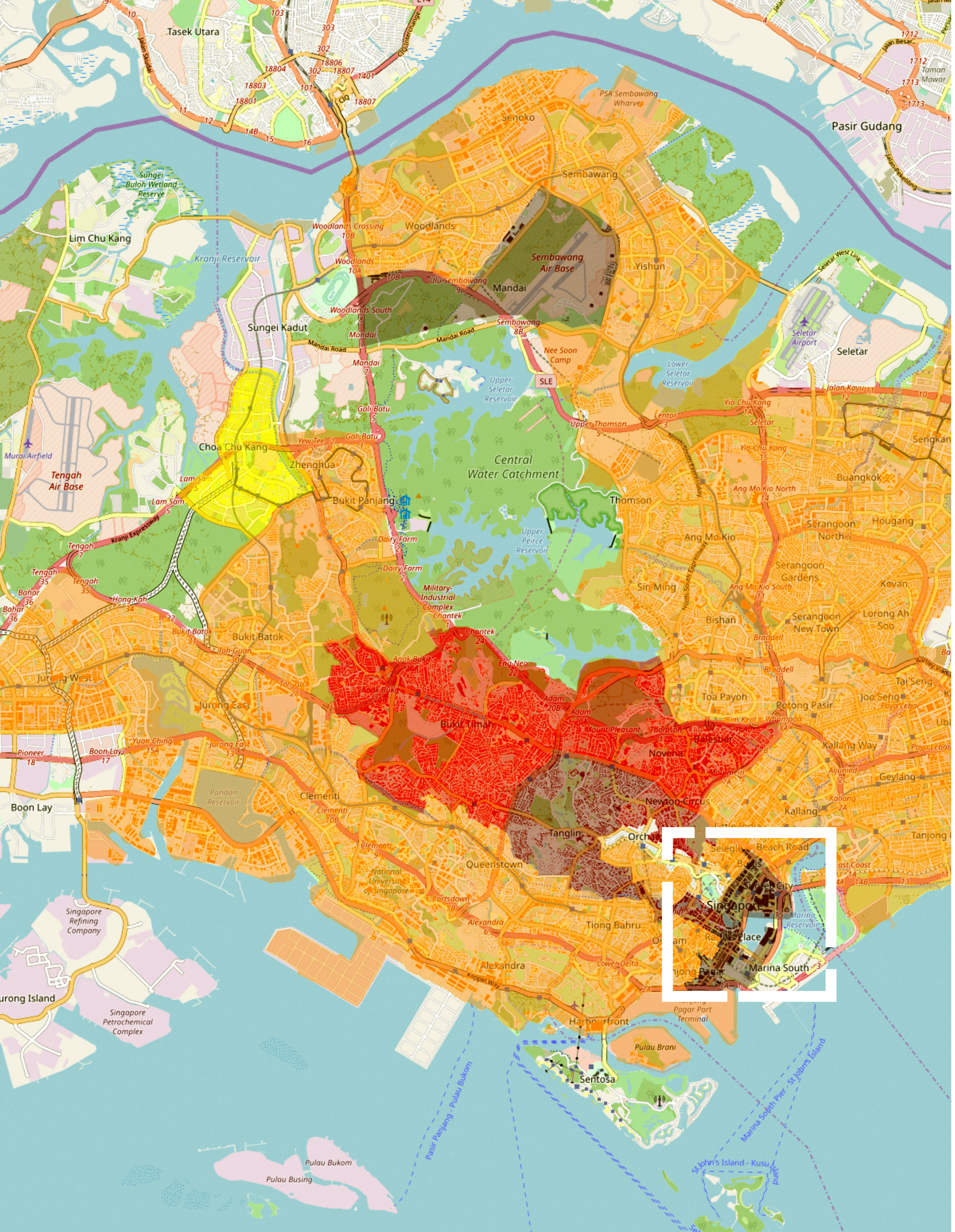
GIS-BIM integration delivers benefits across the life cycle of a project. In the early phases, one of the attractions is the ability to combine information from multiple sources in different formats to clearly identify and review project constraints or potential issues.

A key element of this capability is the digital submission of project plans. Digital submissions reduce the time needed for plan reviews. With digital plan submissions, multiple agencies can review the same plans in parallel, reducing turnaround time. Making necessary changes or updates happens with just a few clicks instead of a costly reprint or the expense of mailing revised paper-based plans.

Digital submissions that combine GIS and BIM enable the sharing of rich content and data across organizations.

In optimal cases, GIS becomes the platform for digital submissions. Though many vendors offer different types of digital submission software, GIS stands out in its ability to put those submissions to work. Inside GIS, digital submissions become dynamic data that can be mapped, searched, analyzed, and investigated.

Finally, in addition to saving time and money, the positive environmental impacts are meaningful. In the United States in 2016, it was reported that annual office paper consumption was enough to build a wall that's 6,815 miles long and 10 feet tall. That's greater than the distance from New York to Tokyo. Additionally, by converting to digital submissions, 35–45 gallons of water is saved for every pound of paper that is no longer needed. ■



About Esri

Esri, the global market leader in location intelligence, offers the most powerful mapping and spatial analytics technology available. 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 more than 7,000 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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