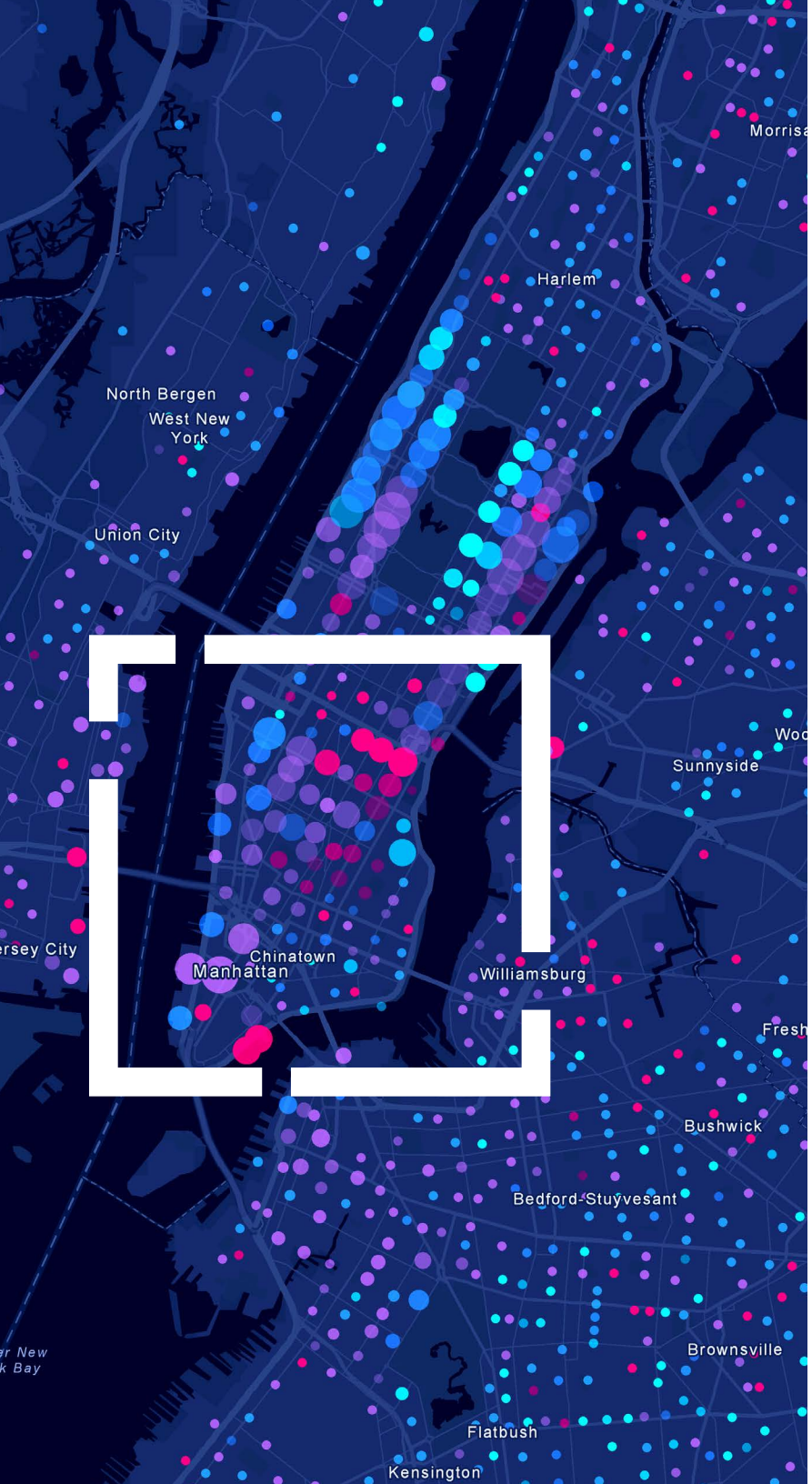
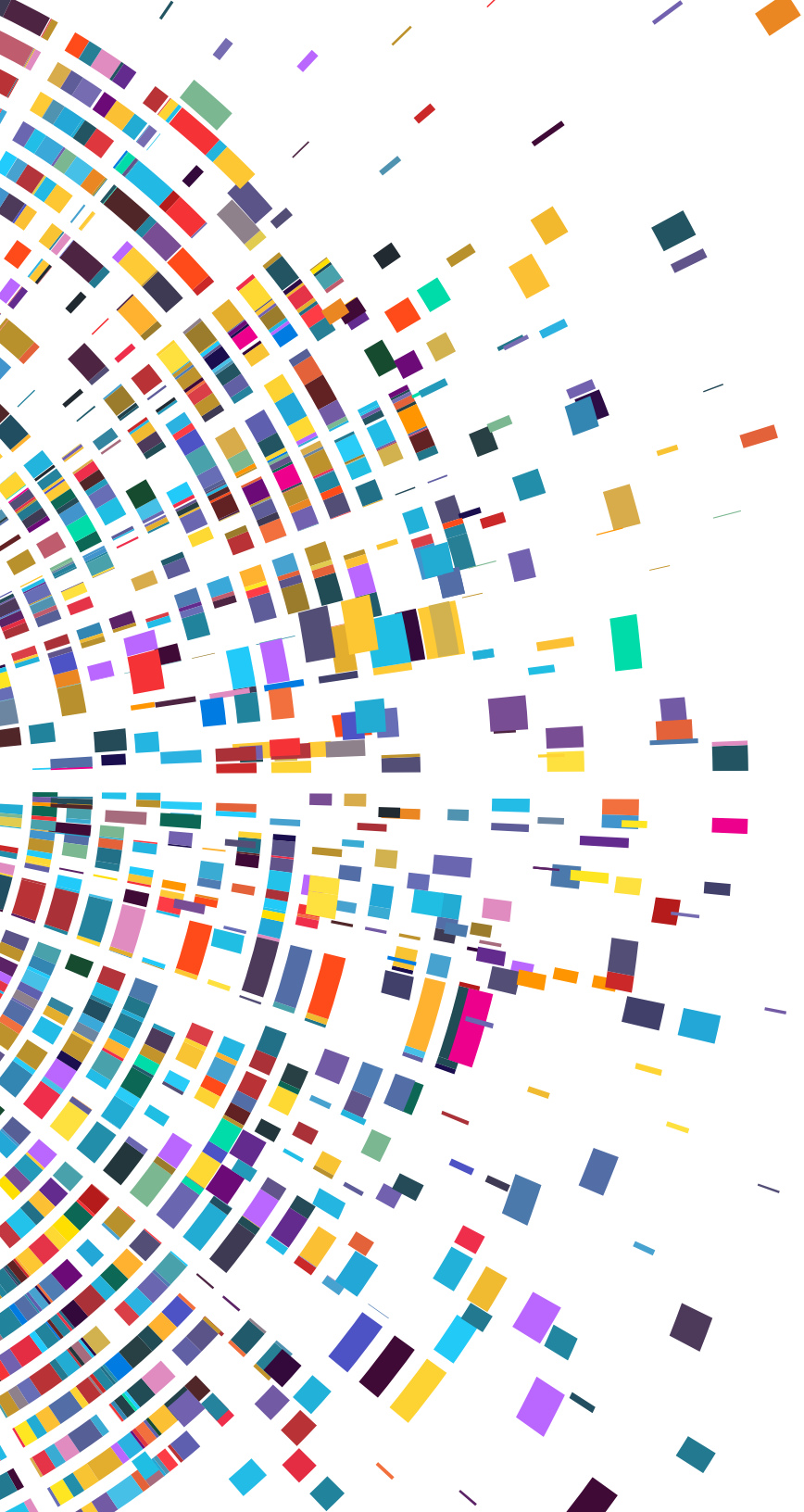
MONITOR CITYWIDE ACTIVITY IN REAL-TIME

How sensors, AI, and live maps help cities manage risk, maximize resources

esri | THE SCIENCE OF WHERE®



WHAT'S INSIDE



Executive Summary

The Need and the Capabilities

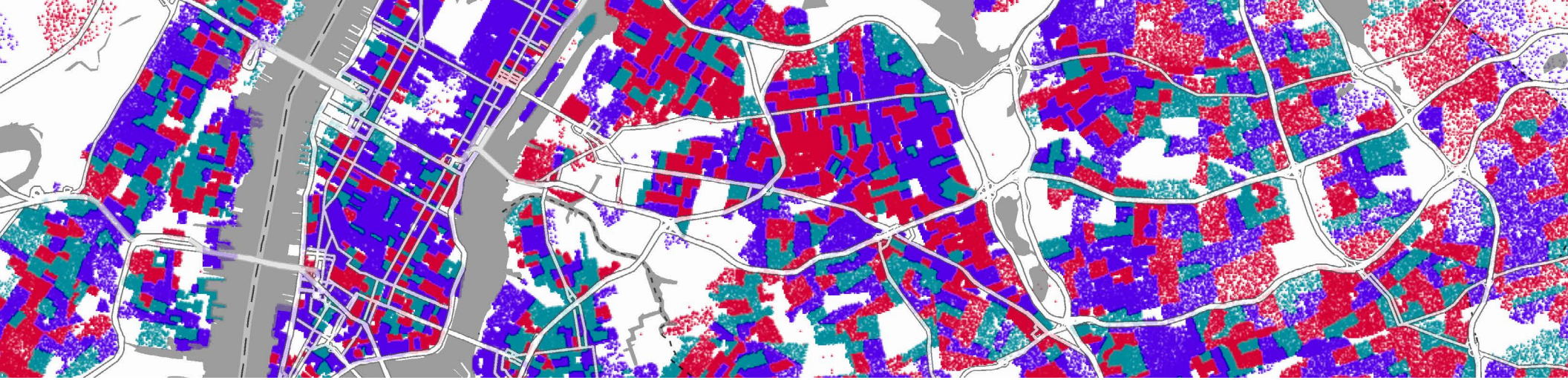
The Big Idea

Around the world, complex organizations are applying apps, drones, artificial intelligence (AI), machine learning, and the internet of things (IoT) to populate a real-time view of assets and people on a shared map. A modern geographic information system (GIS) combines data collection, analysis, and sharing to achieve operational intelligence. With these tools, organizations gain an edge on complicated challenges because they can see trouble coming and manage decisively around it. For cities, the same tools help deliver services more efficiently and cost-effectively, with the added benefit of a map-based awareness of residents to ensure that all communities are well served.

Here's the *Why*

Despite high walkability and the most extensive mass transit system in the United States, New York City remains America's third-most congested city. The issue is not simply traffic congestion itself. Other factors such as climate-related weather extremes, power outages, and public events or protests have mobility impacts that add to the ripple effects—impacting all facets of doing business in and for the city.

Decision-makers and operations officials require a real-time management tool that enables them to see the current condition of the city and use that information to make better decisions about resources, people, assets—in other words, the city in its totality. And these leaders need to see it not just as it is now, at the moment, but also how it is likely to shift in an hour, a day, or a week. They need a tool that provides a visual means to understand the full context of the city, and the way the context affects—and is affected by—the movement of people and assets. They need a technological solution to see what's happening and query across space and time to make crucial resource management decisions, acting proactively rather than reactively.



Executive Summary (continued)

Using GIS technology can accomplish these interwoven objectives, with a suite of tightly integrated tools that can achieve several goals simultaneously:

- **Collect, Analyze, Share**—Use purpose-built, location-based apps to collect data and optimize the efficiency of field activities. Then use GIS in the office to store, map, and analyze data points to see challenges in their totality. The data, map products, and analytical results can all be shared internally, across departments, with partners, and pushed back and forth to and from the field.
- **Spatially Enable Operations**—Operational awareness delivered by GIS lets managers see what is happening, track mobile employees, reduce mileage and fuel costs, save time and wear and tear on vehicles, and push routes and directions directly to the field to simplify communications and speed services.
- **Achieve Real-Time Intelligence**—Ingest massive volumes of real-time data feeds and perform fast queries and analysis to understand movement and change. Cities are increasingly constructing digital twins, which combine a 3D model with IoT sensor data to see activity and the workings of the urban environment in real time. This real-time awareness allows users to see such things as bottlenecks in traffic as it changes, where to respond, and where there are service gaps.
- **Integrate Important Business Systems**—GIS provides a common meeting ground for other enterprise systems through a powerful factor—location. Through this primary attribute, contained in an estimated 80 percent of all records, relationships are established and data from multiple systems can be seen, queried, and acted on. Esri has strong partnerships with providers of foundational enterprise technologies such as Microsoft, SAP, and Salesforce, adding the power of location intelligence.
- **Really See the Situation, with Great Clarity**—Because GIS contains tools to understand people, things, and processes, it provides unique context. This transparency helps create a smart community. It's about being empowered through our devices, giving everyone fast and right answers, and getting to consensus quickly.
- **Bring Stakeholders Together for Shared Solutions**—By constantly collecting and storing data and providing the means to visualize it on maps, GIS allows decision-makers to note historical patterns and devise solutions. Using machine learning and other AI tools, planners can forecast outcomes. Managers also use GIS to organize people to collect and analyze data around initiatives. GIS workflows underpin good decision-making by helping users analyze the data at hand, target the workforce to take action, and then monitor progress.

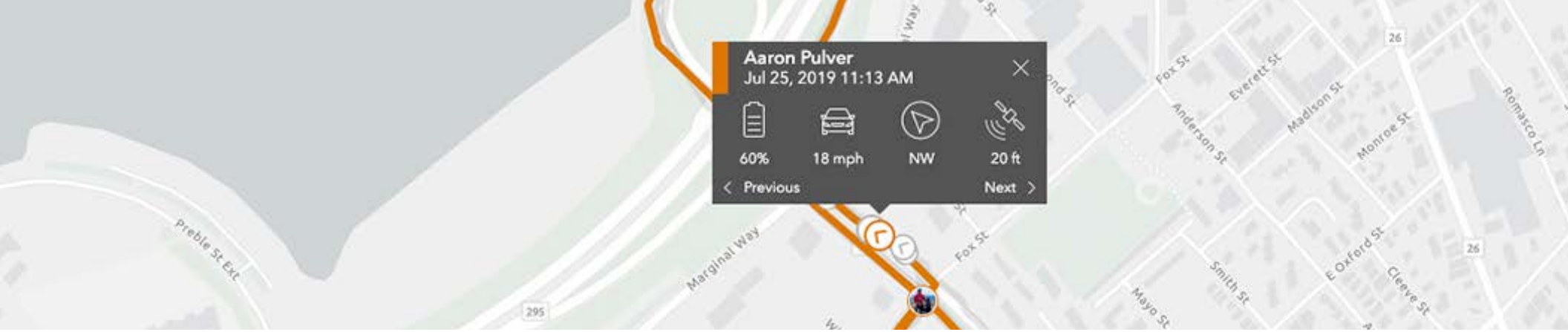
GIS manages this level of complexity while bringing visibility to problems and awareness of progress toward the sustainability goals that define a resilient city for the 21st century. ■

SECTION 1

REAL-TIME FEEDS FOR MANAGEMENT

Managing city resources effectively requires real-time situational awareness for problem-solving in the moment. A GIS-based operational intelligence system gives officials the power of a shared map that incorporates the totality of its enterprise information repositories. Real-time data connects the city's current situation with the events unfolding around it. Seeing business data and current status on a map gives officials the confidence they need to make proactive decisions.

GIS can bring data together from disparate sources, while smart maps offer a comprehensive view of what's happening now. Weather reports, incidents, construction activity—it all comes together to provide full awareness of current conditions and ways to improve them. With access to historical data, trends and patterns can be uncovered to guide decisions. Armed with location intelligence, management can proceed at peak performance levels and achieve service excellence. ▶



Section 1 (continued)

Three new ArcGIS® products add important real-time perspectives that enhance an organization's situational awareness:

ArcGIS Velocity℠ is a cloud-native software as a service for ArcGIS Online that allows organizations to ingest data from IoT platforms, message brokers, and third-party APIs. It helps users process, visualize, and analyze real-time data feeds; store them as big data; and perform fast queries and analysis. This capability adds an awareness that brings clarity to essential operational decisions, allows for remote monitoring of important assets, and provides key inputs to achieve predictive maintenance and process optimization.

ArcGIS Tracker is a mobile app that enables organizations to capture the tracks of field staff, monitor where they are, and analyze where they have been. Knowing where personnel are enhances safety, allows organizations to dispatch the closest personnel to respond to unplanned events, ensures adequate coverage, and lets managers check if field personnel are on task. Patterns derived from tracks give decision-makers the ability to examine productivity and create efficiencies in field activities.

ArcGIS Field Maps integrates the ability to capture data with easily configured forms, combine position and locations on a map to find assets and route to the work, and improve transparency between the field and office by seeing tasks alongside the location of the workforce.

Each of these tools speeds an organization's ability to gather data at high volumes to provide context. GeoAI—a combination of GIS and artificial intelligence programs—helps fill in data gaps and automate analytics to tease out information from dataflows. Using deep learning models, GeoAI performs three crucial functions. It sorts through large image caches, recognizing and categorizing the depicted objects by using pattern detection algorithms; discerns change and trends amid enormous amounts of data; and makes authoritative predictions based on current conditions compared to historical data.

GeoAI allows cities to be even more proactive. Just as deep learning programs can recognize shapes and objects, they can also sense patterns in the data that are not otherwise apparent. This kind of analysis gives operational leaders advance warning of unfolding events.

A deep learning program can even integrate historical data to help users make informed predictions. The system can integrate data from remote sensors around the city, leveraging big data and IoT to improve resource management as part of a smart-city approach. ■

CASE STUDY

LONDON

Real-time Location Sits at the Center of London's Traffic Management

The Situation

Twice in the last decade, Londoners have seen dramatic shifts in the way they interact with streets and transit. The first was in 2012 when the Olympic Games temporarily brought 600,000 new riders to London's buses and trains. The second was in 2020 when the COVID-19 pandemic emptied streets, buses, and rail cars.

The Challenge

During the Olympics, Transport for London (TfL) had to move people around to the many venues while maintaining mobility for residents and businesses. In response to the pandemic, it had to reconsider how mobility can enhance public safety.

The Solution

In both instances, TfL planners looked for real-time understanding of traffic patterns, demand levels, and incidents using situational awareness from a geographic information system. In 2014, TfL reinforced its GIS and began delivering GIS as a service to other key enterprise systems.

The data and layers captured in TfL's GIS describe locations and things, including up-to-date details about roadways, rails, paths, and all the physical assets the agency maintains. Sharing this capacity as a service means that other systems can ingest and build on authoritative data and visualize, query, and analyze it for specific purposes. ▶

The Real-Time Origin Destination Tool (RODAT) analyzes feeds from video cameras at key locations and along major routes in central London. The tool monitors conditions between more than 20,000 origin and destination pairs every 15 minutes to calculate actual journey times and traffic flows to keep London moving.

London (continued)

TfL undertook a major digital transformation in 2016 with its Surface Intelligent Transport System (SITS), an umbrella project that modernized traffic signals, incident management, and coordination of road improvement.

TfL's GIS as a service directly feeds the agency's adaptive traffic signal system. Data from sensors in the road network feed the split cycle offset optimization technique (SCOOT) model, which analyzes volume, second by second. Buses and their locations in the queue are also modeled and monitored. Then, the model feeds junction controllers in real time to adjust traffic signal timings to take advantage of each road's volume versus capacity and coordinate flow with neighboring roadways.

TfL's operational knowledge, captured in GIS, helps improve traffic flow as well as the environment for walking and cycling. One of the traffic signal innovations that have been tested during the COVID-19 pandemic involved the Green Man Authority—a pedestrian traffic signal that shows a green man continuously until any vehicles arrive.

GIS and the SCOOT system also feed an advanced big data analytics tool to understand dynamic changes in road traffic. The Real-Time Origin Destination Analysis Tool (RODAT) analyzes feeds from video cameras at key locations and along major routes in central London. The tool monitors conditions between more than 20,000 origin and destination pairs every 15 minutes to calculate actual journey times and traffic flows to keep London moving. ▶

GIS is also at the center of TfL's LondonWorks system for the coordination of road improvements, with a registry of all roadwork and street-related events, both planned and current, in Greater London. LondonWorks maps all incidents and uses spatial analysis to assess road networks and then coordinate various roadwork to minimize congestion.

All inputs are combined in TfL's Traffic Information Management System (TIMS) to monitor and manage traffic by using a GIS database of live and planned traffic disruptions in London, including congestion, traffic incidents, repair work, and special events. TIMS allows media agencies and other stakeholders to view disruptions in real time (updated every five minutes) and see information about planned activity likely to impact traffic—providing a shared situational awareness.

The Results

Maps provide a powerful, visual understanding of mobility capacity as well as a strong platform to plan, prioritize, and improve roadwork projects. The Olympics effort was deemed a success, with 90 percent of journeys completed on time despite a record number of riders. The London Tube alone had 4.5 million riders on one day of the Olympic Games, compared to the typical day's 2.5 million, and 30 percent more riders than usual over the course of the event.

During the current pandemic, TfL's system has allowed the agency to support London's goals for active, sustainable transportation while creating more space for fewer people. Streetspace for London projects encompass widening walkways, creating temporary bicycle lanes, and restricting car traffic near schools and in designated low-traffic neighborhoods. Streetspace projects have been built citywide on the 360 miles of roads, quickly reimagining streets and roadways to keep city residents active and socially distant during the unprecedented COVID-19 pandemic. ■

SECTION 2

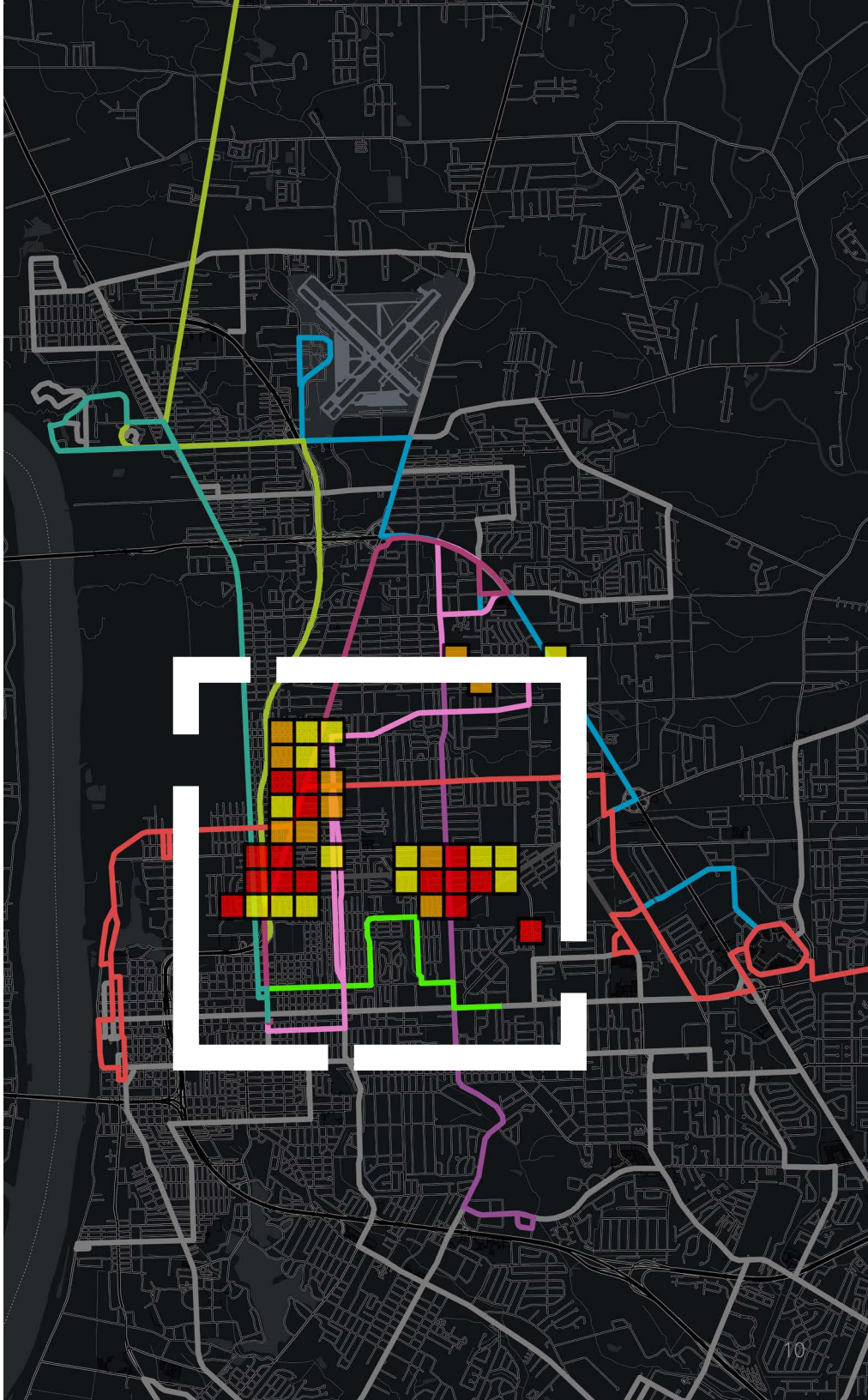
ADOPTING A DATA FUSION CENTER APPROACH

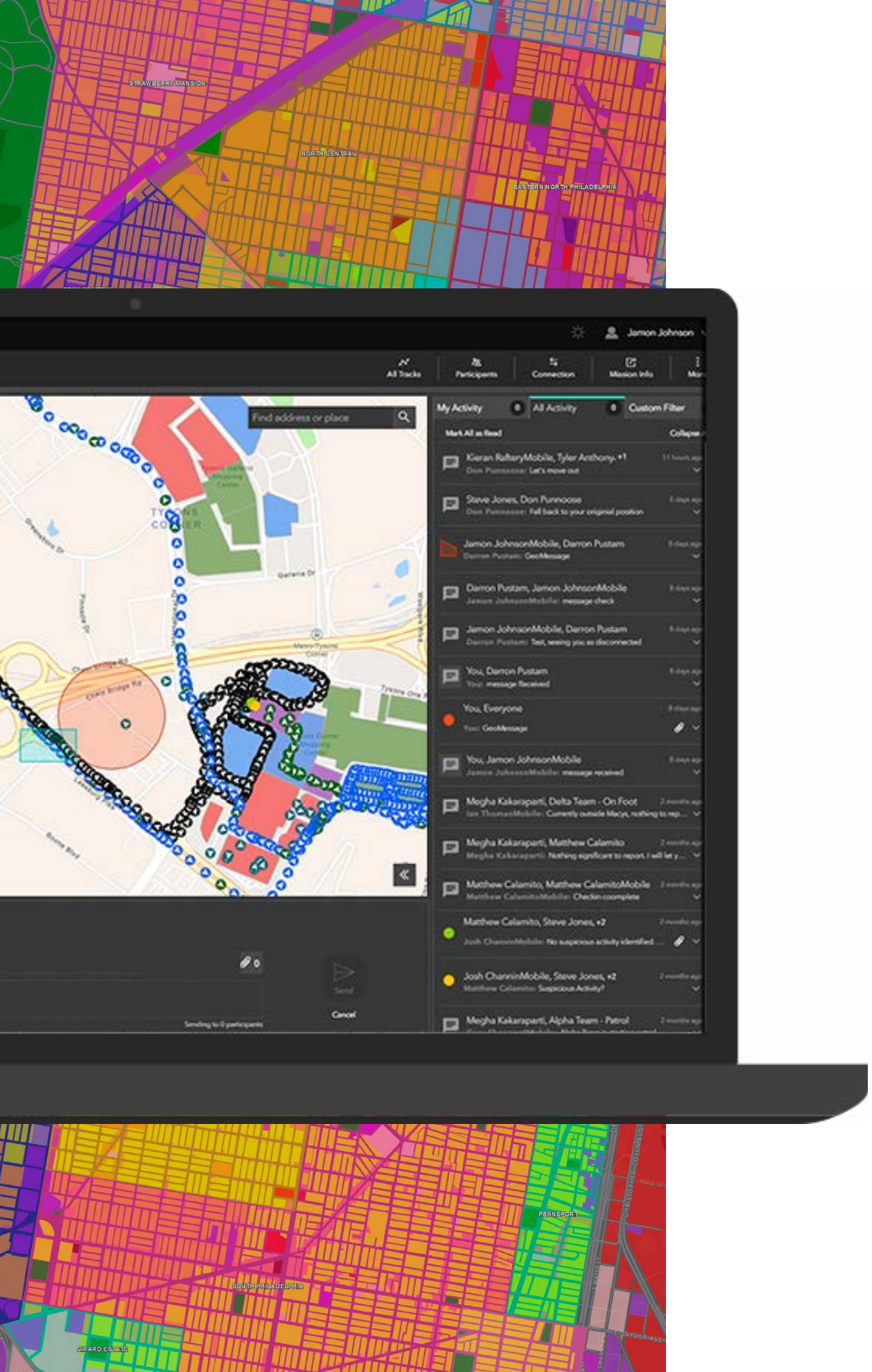
The concept of the fusion center is familiar to public safety agencies—especially when monitoring large events. It's a concept that's larger than that of an Emergency Operations Center, because it's about the flow of all relevant incident and condition information across all government parties—federal, state, and local. A fusion center provides a way to synthesize information coming in from the field. Managers at the center can gain a holistic view of the situation, making changes and adjustments as necessary. Maps are often an important tool for understanding the larger context of an event.

The thing that these centers "fuse" is intelligence. They allow all key stakeholders to make connections and change plans as necessary.

The fusion center model can apply to a city as a whole, which can be thought of as a giant gathering that never disperses. Instead of a department-by-department capability to see just what one group is doing, a fusion center for a city combines all inputs for increased situational awareness and improved collaboration. All manner of movement can be tracked—from cars, commercial vehicles, mass transit, pedestrians, and cyclists. Add to that the work being done to deliver city services. Combined, the fusion center constitutes the ever-changing context of the city.

Fusion centers don't need to be physically fixed entities. With the myriad of IoT sensors in the modern city providing a constant influx of information and data, a fusion center can be dispersed into a common virtual environment. ▶





Section 2 (continued)

By realistically modeling physical space, GIS creates an operational intelligence environment. The virtual fusion center, powered by GIS, expands the system to a new level of utility.

A GIS-powered fusion center is akin to an intelligent nervous system. The people at every node of the system—from managers at various city agencies to workers dispersed around the city—have access to all the signals to gain operational awareness.

With cloud-native capabilities like ArcGIS Velocity, which gathers IoT data and puts it in geographic context in near real time, important decisions can be made with minimal delay and maximal intelligence. The flexibility of the cloud ensures that the system flexes and grows, keeping information flowing regardless of data volume.

A GIS-powered fusion center can gather data from different devices collected in the field, process it, and show it on maps where patterns and bottlenecks emerge in near real time.

True operational awareness requires many stakeholders operating in concert, from workers in the field to managers monitoring situations from the office. A fusion center facilitates data sharing and discourages data siloing. GIS becomes a common meeting ground for information, revealing the interlocking nature of various datasets.

The modern smart city produces so much data that it can be hard to discern the signal from the noise. Dashboards integrated with maps allow numeric and statistical information to be stored and assessed.

When accidents or other events related to public safety occur, managers need an up-to-date picture of the location of mobile workers who can manage the situation at the scene and transmit situational updates from the field. Virtual fusion centers may not have a single location like their physical counterparts, but they still allow managers to understand the location of those they manage. GIS-generated maps facilitate a quick assessment of who is where, and where they ought to be to handle any situation. ■

CASE STUDY

PENNSYLVANIA

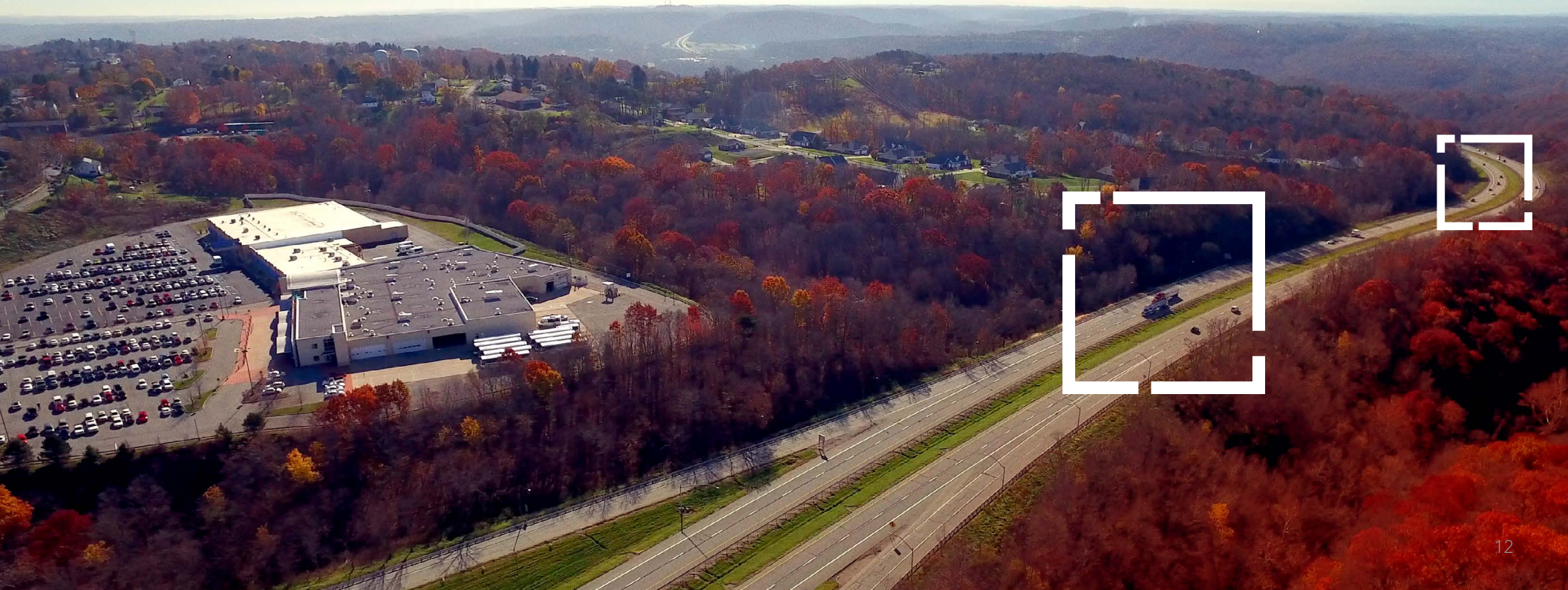
Pennsylvania Turnpike Commission's GeoAnalytics Program for Analyzing Big Data

The Situation

The Pennsylvania Turnpike stretches for over 500 miles across the state, from the border Pennsylvania shares with Ohio to the bridge leading into New Jersey. The turnpike connects Pennsylvania's metro areas and traverses the Appalachian Mountains, carrying goods to and from America's fifth-most populous state.

The Challenge

The Pennsylvania Turnpike Commission and its nearly 2,000 employees have made great strides toward creating a data-driven operation, including the extensive use of GIS. The GIS-based efforts began with a web mapping app built by turnpike authorities. Incident data from Pennsylvania State Police was displayed on a map and revealed areas where accidents were especially likely to occur. With this early success, the turnpike authorities realized the toolset could do more, and that cemented their desire to apply GIS on an enterprise level. ▶



Pennsylvania (continued)

The Solution

In 2018, the Pennsylvania Turnpike Commission launched the GeoAnalytics program to create geography-based projects for departments within the commission. Among them is the Traffic Operations Center, which monitors all activity on the freeway.

The Results

Dashboards and maps integrate data from several sources, including weather alerts; traffic cameras; and the commission's vehicle fleet, automatically transmitting location data and road conditions from sensors on each vehicle.

A partnership with the navigation app Waze gives the center alerts promptly, allowing the commission to respond quickly to incidents and accidents. When incidents occur, the information gets automatically routed to the right people, including police, firefighters, paramedics, and towing companies. Location information is also used for traffic management, department reports, and various alerts and to improve the data on travel maps.

GIS also helps the commission make improvements that make the flow of traffic safer and smoother on the turnpike. For example, information about locations of deer strikes, shown on the map, allowed officials to note certain hot spots of animal activity and strategize safety measures, including the creation of animal overpasses so that migrating animals are unimpeded by human traffic. ■

SIDEBAR ELEVATING SERVICE WHILE ADDRESSING INEFFICIENCIES

With budgets constrained by the economic setbacks of the COVID-19 pandemic, cost savings are top of mind for all organizations. Decision-makers with control of spending—and the need to slash costs—are looking for every efficiency. An operational intelligence system powered by ArcGIS provides opportunities to increase the flow of field activities—eliminating friction that slows service delivery, synchronizing work that must happen in sequence, and compounding incremental savings into large cost reductions.

One key contribution of an operational intelligence system is in the area of mobility. The system is being applied to many of New York City's fleet vehicles, and managers use it to route workers and crews to where they are needed. New York City saves money daily by using GIS to manage field operations while improving the delivery of city services. Imagine the savings if this were common practice across all departments, and with the added benefit of shared visibility.

United Parcel Service, Inc. (UPS), fields a supersize suite of these same capabilities—alongside sophisticated algorithms and big data analytics—to guide deliveries and analyze routes. The On-Road Integrated Optimization and Navigation (ORION) system famously led the company to eliminate left-hand turns because they increase idling time and burn more fuel. Also, UPS logisticians have come to realize that eliminating one mile per driver per day over the course of one year can save the company $50 million.

When UPS set about its pioneering work to equip each driver with a data-collection device, it was before the advent of smartphones, so the company engineered its own handheld devices. Now, devices are ubiquitous, and apps can be easily configured to address common city management workflows.

As UPS found, an operational intelligence system improves dataflow and adds situational awareness, which provides the means to cut costs while improving service delivery. It's beyond time to eliminate paper-based processes. ■

SECTION 3

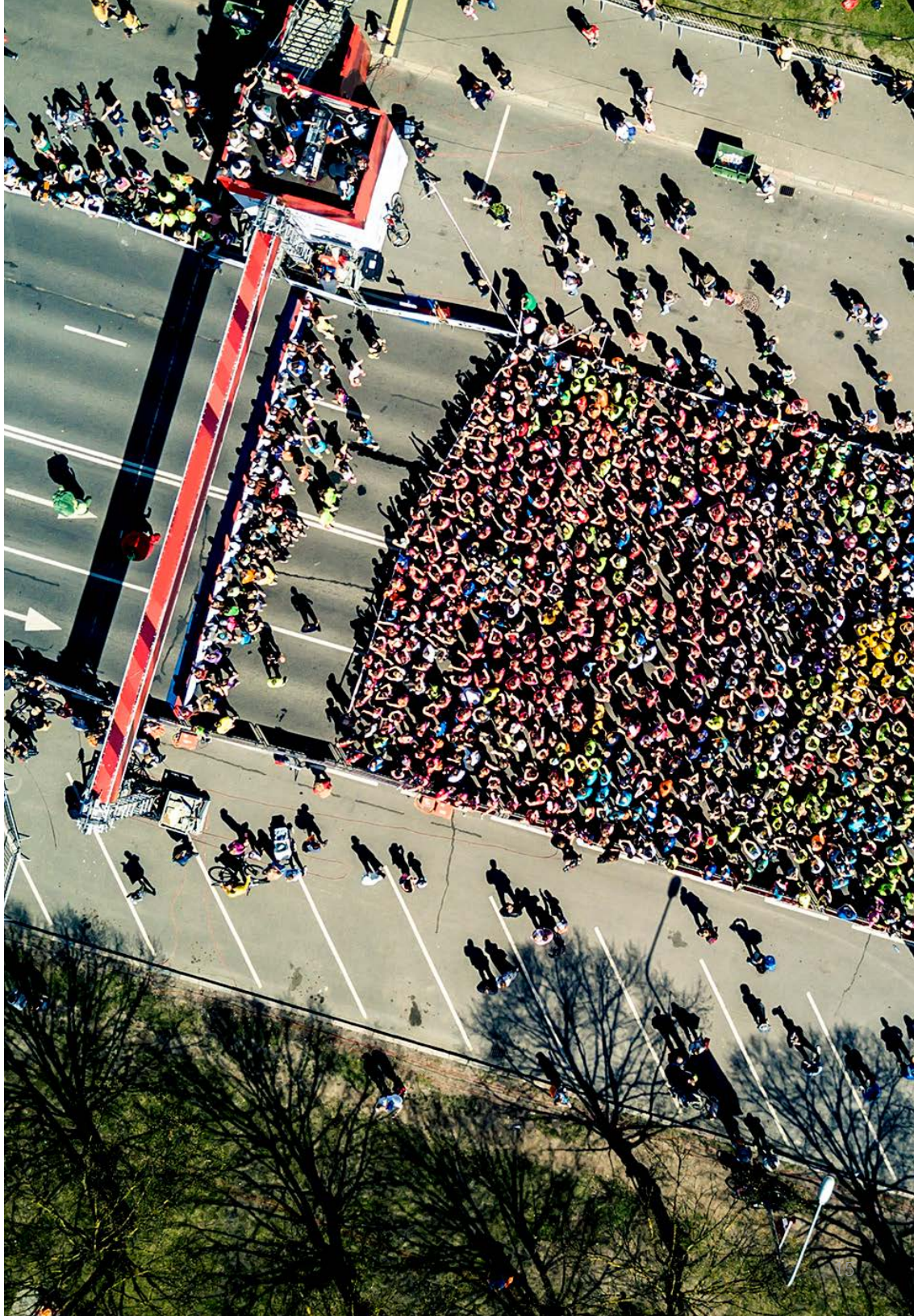
MANAGING COMPLEX SPECIAL EVENTS

When the social distancing provisions of the COVID-19 pandemic are no longer necessary, cities will go back to holding large sporting events, concerts, and multiday festivals. Experts predict that special events will be in high demand as we leave behind the isolation of stay-at-home orders and get back to active social lives.

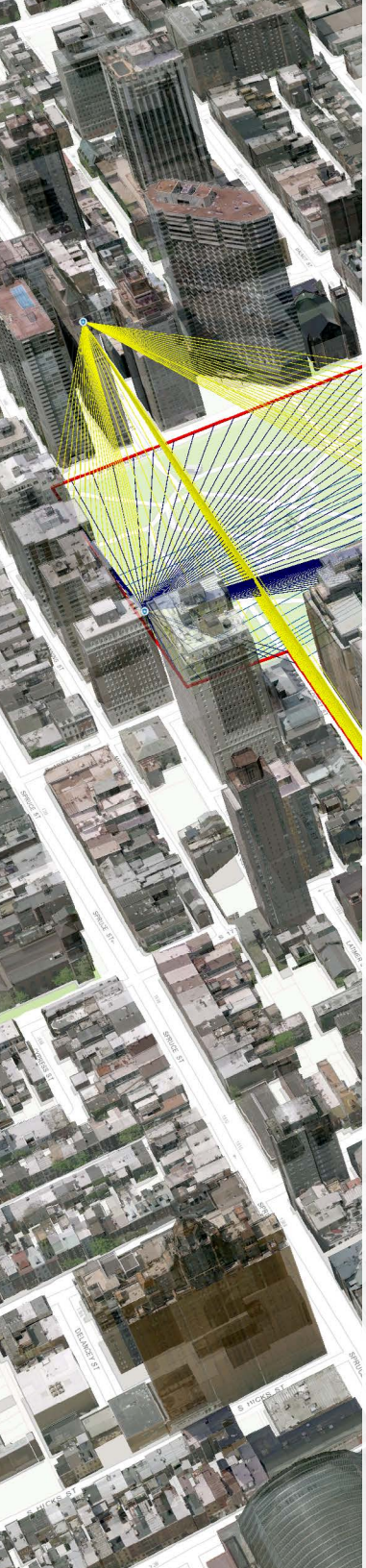
Threats from public protests and extremists will likely not go away, however, and a new level of operational awareness is being applied by public safety and governmental agencies to deal with incidents and increase on-site collaboration to avoid tragedies of every kind.

ArcGIS Mission provides a GIS-centric command and control system to streamline event management for public safety and operations managers, and provide tactical teams with situational awareness. It provides tools to manage individual officer assignments to protect key assets, manage critical incidents, and to plan for contingencies. All key mission data, such as messages, photos, and location tracks, are stored for after-action review and playback. The Mission mapping system supports public safety workflows to secure special events while aligning the efforts of local, state, and federal agencies to act in concert.

Drones have become a key source of input for the early assessment and ongoing monitoring of event sites, capturing high-resolution and up-to-date images of the event setup so that officers can orient themselves quickly should an incident occur. These inputs can easily be integrated in GIS, and Esri has a portfolio of drone tools to derive intelligence from raw images. ▶



Section 3 (continued)



Esri also offers a number of solutions that take the core GIS capabilities and tailor them for special-event and emergency management operations. These solutions provide a way to collaborate in a geographic context to simplify the safety planning and operations workflows. Event information from the incident action plan can be mapped and monitored along with live information such as weather and traffic conditions, field reports, and health and safety hazards.

Special events play an important role in local economies and improve a community's quality of life. Often these events are celebrations of history or heritage that draw people together and instill close community connections, which will be in high demand after more than a year apart.

For a city as dynamic as New York, the value of this kind of real-time intelligence system extends far beyond events: In the world's major cities, it's not an overstatement to say that the daily challenge for managers of achieving operational excellence and keeping people safe is the equivalent of pulling off a massive special event every single day. ■

CASE STUDY

ATLANTA

Real-Time Data and Maps Aid Atlanta's Super Bowl Efforts

The Situation

With an anticipated attendance of more than 70,000 fans and a global television audience of more than 100 million people, Atlanta city officials knew they had to be prepared to make the event safe and successful for the 2019 Super Bowl.

Serious operational preparations started six months ahead of time, in July 2018. The game—scheduled for February 3, 2019, at Mercedes-Benz Stadium—was just one of many Super Bowl events the city needed to be ready for. Pregame festivities, entertainment, and concerts would be drawing large crowds over a 10-day span.

The Challenge

Public safety and operations professionals from all across the region, and from federal partners, needed to combine their expertise and information across multiple emergency operations centers (EOC). Teams from different agencies and with many specialties needed to all mesh and coordinate activities for all the days of this multiday event. These organizations needed a way to create a real-time shared situational awareness to keep the events safe. ▶

The Solution

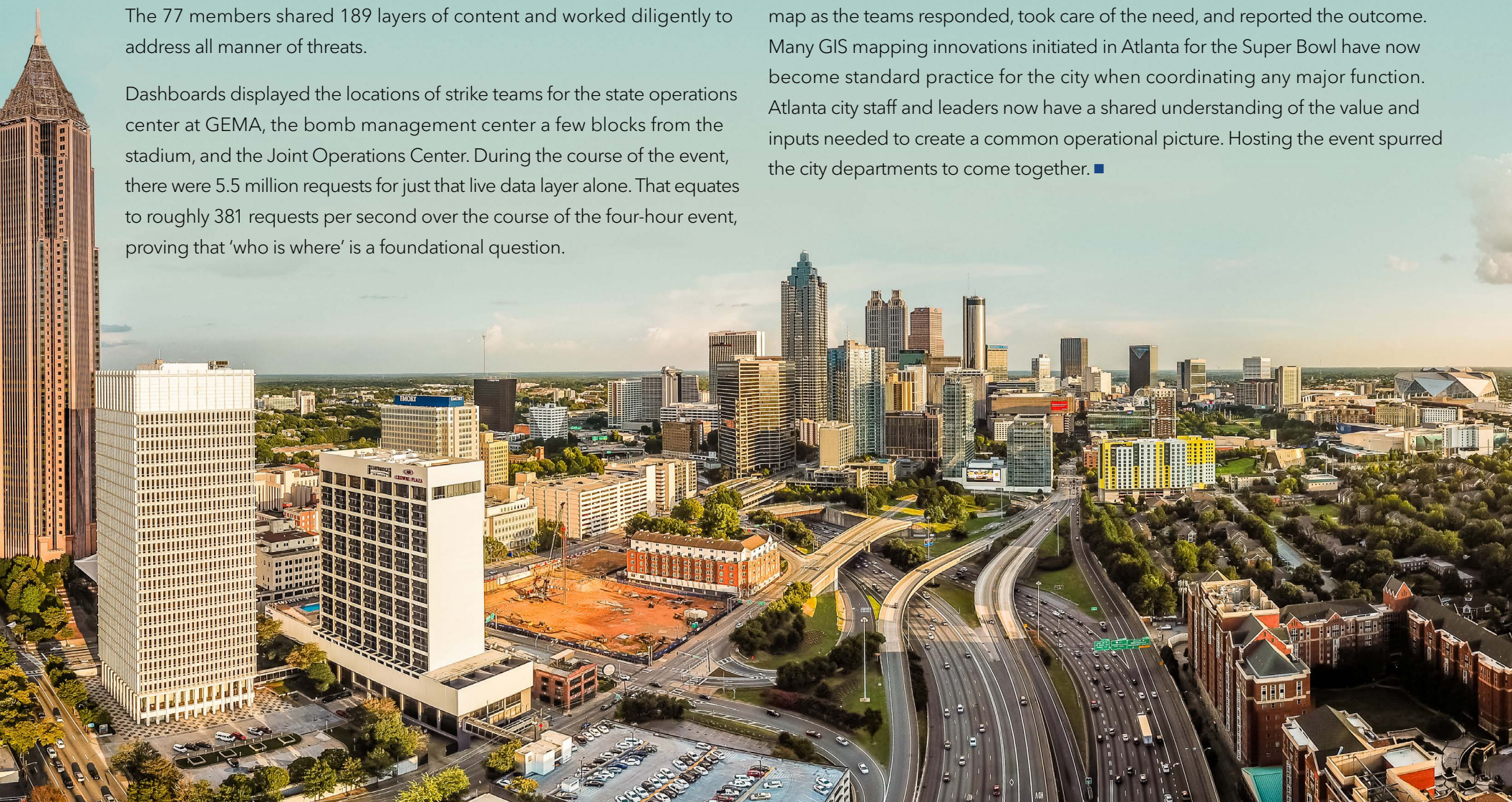
A broad range of organizations that work with GIS on a daily basis came together to help the city with its special event plan. They collaborated and shared data using ArcGIS Online. Participants included staff from multiple departments of the City of Atlanta, Fulton County, Cobb County, the Georgia Emergency Management Agency (GEMA), the Georgia Bureau of Investigation, the FBI, the Federal Emergency Management Agency, and the Department of Homeland Security.

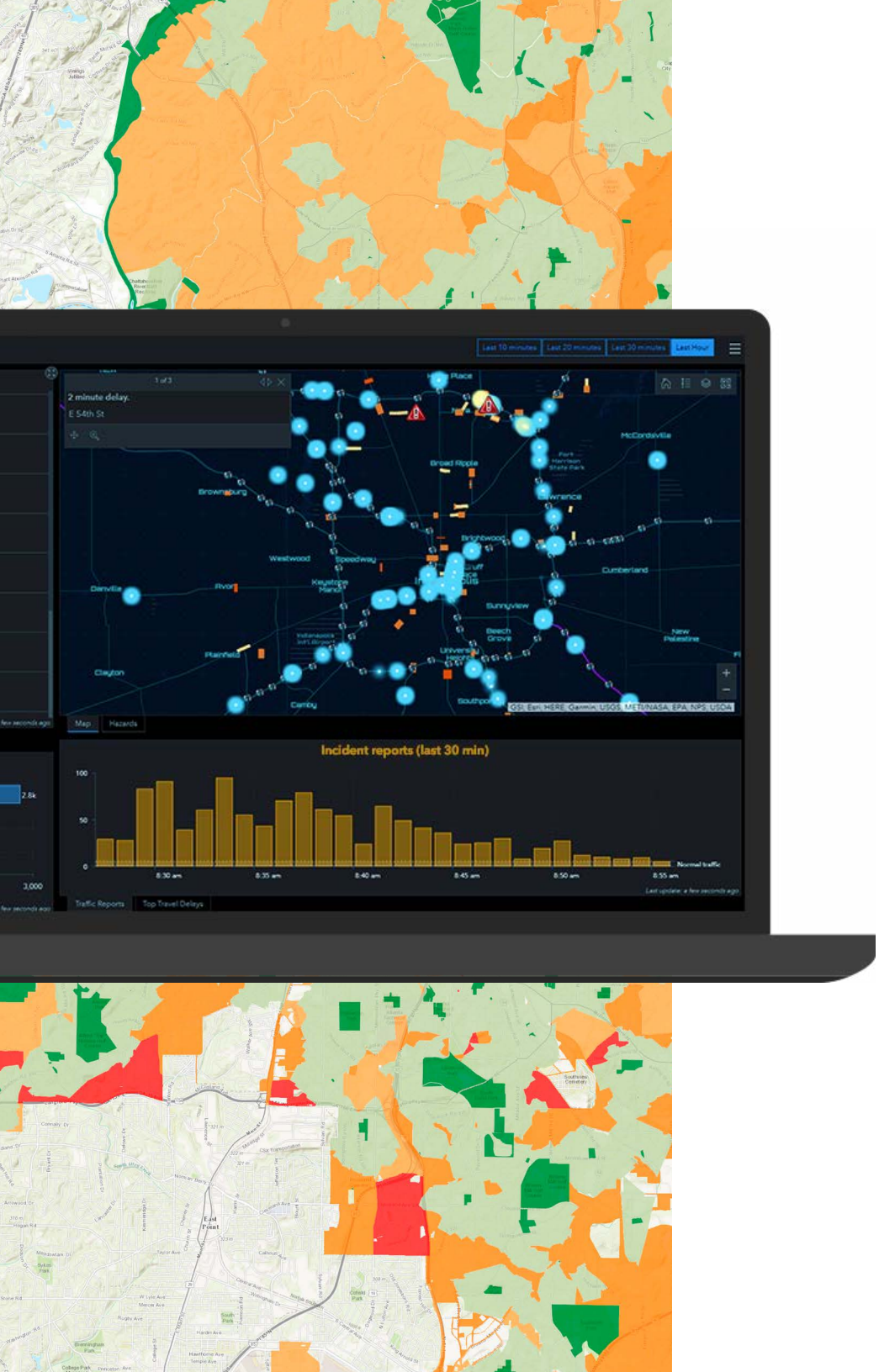
The 77 members shared 189 layers of content and worked diligently to address all manner of threats.

Dashboards displayed the locations of strike teams for the state operations center at GEMA, the bomb management center a few blocks from the stadium, and the Joint Operations Center. During the course of the event, there were 5.5 million requests for just that live data layer alone. That equates to roughly 381 requests per second over the course of the four-hour event, proving that 'who is where' is a foundational question.

The Results

The ability to seamlessly integrate location data between systems and across agencies went far beyond data sharing between GIS peers. The real-time location sharing unlocked an additional level of collaboration, allowing everyone to see who was closest to an incident and responding together without duplication of effort or the time-consuming distraction of communicating a plan. Instead, everyone saw the convergence of pins representing each person on the shared map as the teams responded, took care of the need, and reported the outcome. Many GIS mapping innovations initiated in Atlanta for the Super Bowl have now become standard practice for the city when coordinating any major function. Atlanta city staff and leaders now have a shared understanding of the value and inputs needed to create a common operational picture. Hosting the event spurred the city departments to come together. ■





SECTION 4

INCIDENT MANAGEMENT

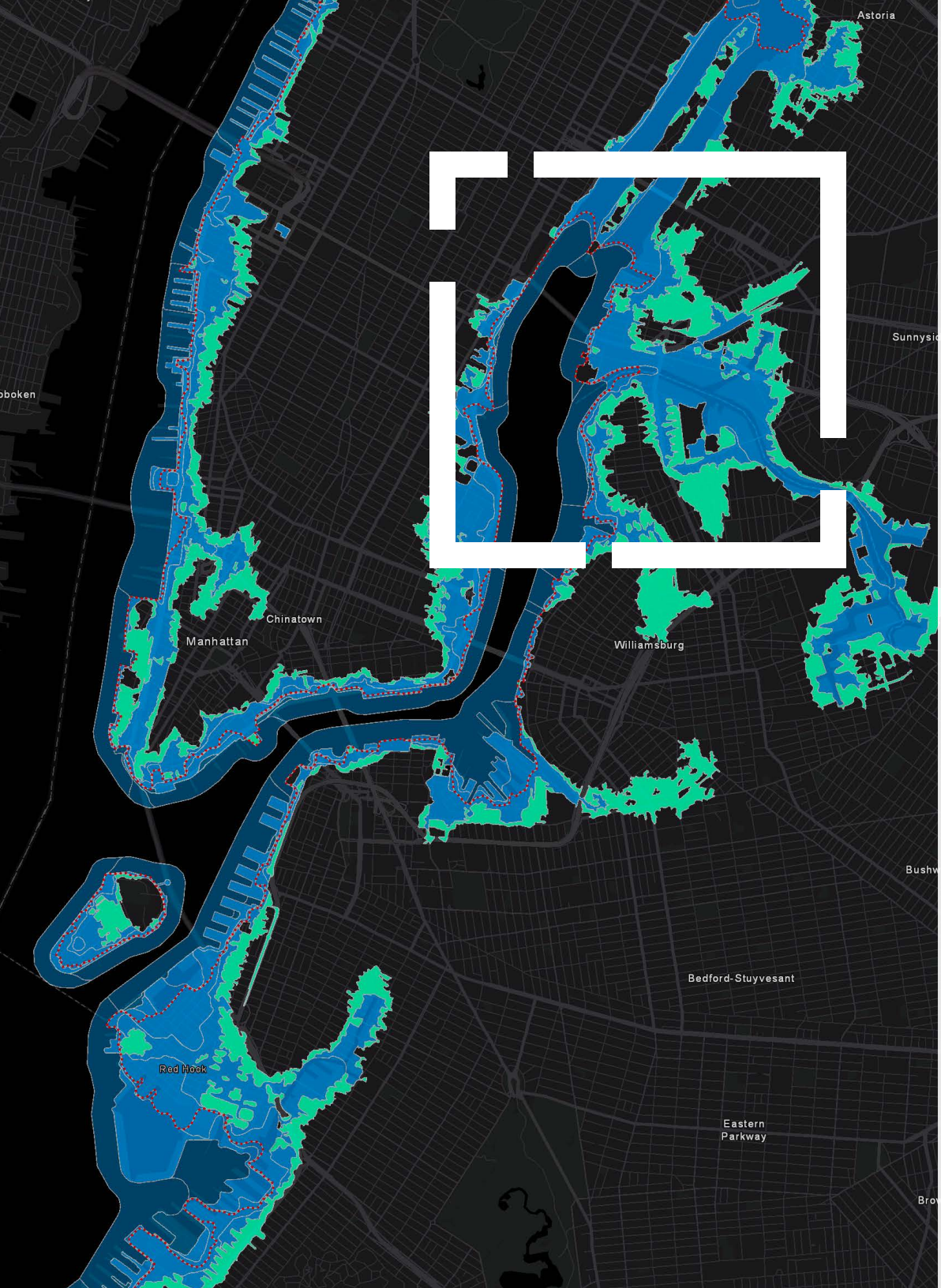
True operational intelligence helps managers see and communicate about incidents, accidents, and changing conditions. An optimal system includes communication channels between agencies, government and citizens, government and businesses, and between governments. The system provides advisories and alerts, so businesses and citizens can make alternative plans, avoid certain areas, or take special precautions. It also provides the backbone of information and communication to coordinate effective action.

The system thereby produces a favorable feedback loop. Advisories alert people, who then become active participants to prevent impacts. The system gathers all useful data points for an intelligent system to understand incidents, recommend changes, and then note the effect of those changes.

The operational intelligence system taps into real-time data from sensors around the city to gauge conditions. The system processes data that is compared to past patterns in order to recommend changes, and then sends alerts and even directs autonomous actions if set thresholds are surpassed.

In the same manner that smart power grids maximize the efficiency of electricity distribution, this kind of system keeps track of the quality of service and pinpoints problems. It creates smoother workflows throughout the city, based on inputs that allow city employees to see their collective actions. It also provides a platform for government to government collaboration, to share and see each other's actions in order to examine incidents, engineer smart solutions, and act together.

This is particularly relevant in a high-density city like New York, where constant change requires continuous flexibility. For instance, construction and infrastructural repairs are perpetually under way amid the non-stop movement of people and goods. Every year, for construction alone, the city's streets are sliced open 200,000 times—an average of nearly 550 cuts per day, or 30 cuts per street mile. An awareness of current disruptions, and planned ones, could greatly benefit everyone. ▸



Section 4 (continued)

A GIS-powered operational intelligence system allows managers to see incidents in their full context. The combination of GIS and AI—GeoAI—can power a system that can detect patterns and hot spots that are not immediately evident by looking at the map. While the manager looks at the big picture and determines what to do across the workforce, individual workers can be sent automated messages to begin dealing with impacts.

A GIS-powered operational intelligence system can serve as a geographically aware information conduit. It can channel incident reports to the right managers, using a location intelligence approach. When there is a flooded street in New York City, for example, the assignment can be sent to the nearest Department of Environmental Protection field crews. A report of a downed power line can be routed to power company crews in the right area. These workers can make notes that update the work assignment, and provide updates about status to everyone.

Managers who embrace the field workforce components of GIS gain an app-powered operational intelligence that provides a full picture of productivity. The common view between the field and office helps make the right things happen when and where they need to. It empowers field workers with real-time awareness and the right inputs—putting institutional intelligence into smartphones to enhance worker knowledge and efficiency. Apps that tackle workflows have been proven to reduce errors, boost productivity, and save money. The more the tools are used, and the more data that's collected, the better the data and decisions become. ▶

In any city—but especially in a dense metropolis like New York—incidents and disruptions do not exist in a vacuum. For example, a stalled subway train can cause backups over the whole system. This, in turn, sends thousands of people out into the street, putting strain on the bus system and pulling more ride-sharing vehicles into the area, which results in even more congestion.

GeoAI can manage the complexity of the situation, understanding the effect an incident has on the city and even offering accurate predictions and assessments of further effects. This data, in turn, can trigger traffic lights to adjust to maintain optimal flow of buses.

Climate change will continue to cause unpredictable events that can inconvenience or displace huge swaths of the city. The same GeoAI system can integrate weather data, helping managers get a head start on dealing with weather-related events.

GIS was originally conceived as a way to store information. The evolution of the technology now means that GIS not only can constantly gather information but also understand it and empower real-time responses. It's a system that enables situational awareness—continuous knowledge that is highly actionable and shareable.

GIS strengthens the relationship between a city's workers, businesses, residents and between departments. It creates a more engaged community, and a general public that has a genuine stake in the pursuit of operational intelligence. ■

CASE STUDY

LAX | Live Incident Maps for LAX's Common Operating Picture

The Situation

From an operational perspective, airports are unique. They not only serve cities and metro areas, they also are themselves the functional equivalent of cities. During a typical year, over 200,000 passengers move through Los Angeles International Airport (LAX)–the United States' third-busiest airport–every day. That means that every month, the number of people experiencing LAX exceeds the population of Los Angeles itself.

The Challenge

LAX sees a great amount of activity every hour of the day, every day of the week. Movement through the airport must be seamless to preclude gridlock and bottlenecks–but given the nature of air travel, security and safety are always major concerns. The airport has 59,000 employees who work in and around the facility–a number that, by itself, is as large as the population of some of the hundreds of cities LAX serves.

This complex web of operations, security, and safety is handled by the Airport Response Coordination Center (ARCC), a command and control facility within LAX. As recently as the early 2010s, communications between mobile workers at the airport and control room staff was handled manually and maplessly, with phones and two-way radios. ARCC was a nerve center of sorts, with field personnel transmitting incident reports to a superintendent, who would then pass assignments to technicians. All information was conveyed verbally, without maps. ▸

The Solution

In 2012, airport officials decided to streamline operations by creating a common operating picture that all staff could access, no matter where they were located on the airport grounds. Key to the setup was a GIS that would add a geographic context to all reports.

ARCC soon expanded on this setup, creating a sophisticated GIS that broke the airport down into various map layers, including airport buildings, infrastructure, and security sensors. Airport staff now use the system, using iPads to initiate incident reports—everything from a fuel spill at a gate to a leaky toilet in one of the airport restrooms. The incidents are marked on maps, and there is room for staff to add associated information, including incident types and photos.

The Results

As incidents at LAX proliferate throughout the day, ARCC staff have a spatially aware sense of the airport's situation as they converse with field crews. Comments are time-stamped to provide an audit trail for each event. This overall view allows the control room staff to send maps out to the field crews to help in problem-solving. If anything requires evacuating travelers, the maps help put in place plans for evacuation.

The maps also make it easier to put in place predetermined plans for responses—where to set up command posts, for example.

The overall result is a system that serves as an information clearinghouse and archive—integrating all workflows and utilizing two-way communication, aided by the organizing power of maps. ■

SECTION 5

DIGITAL TWINS

Rather than merely modeling a city, a digital twin combines the functionality of a 3D model with dynamic dataflows from IoT sensors, allowing managers to see the activity and workings of the city in real time.

A digital twin mirrors physical objects, processes, and relationships. In the context of city management, digital twins are often an extension of 3D models of the urban environment. Rather than merely modeling a city, a digital twin combines the functionality of a 3D model with dynamic dataflows, allowing managers to see the activity and workings of the city in real time.

A digital twin helps a city analyze and present real-time business data with historical trends to see patterns. It presents a single pane of glass view to decision makers that enables them to act wisely.

A dynamic digital twin gives city managers, the workforce, businesses, and residents a single source of truth about the city. It becomes a place to record and query the information about buildings, housing, transportation, water, sanitation, health, schools, and economic development. Digital twins can exist without GIS, in some sort of numeric and tabulation form that updates as the data changes. But without GIS, a digital twin is a faint rendering of the city. GIS brings a digital twin to life. It introduces a geographically aware state by integrating core business systems, unlocking the power of location intelligence, and sharing what all city services have in common—at any given moment. It ties each employee and work order to an event happening at a specific location and provides contextual awareness for all the work happening in the city. ▶

Section 5 (continued)

Using GIS, decision-makers see things as they change throughout the city—and they can make real-time decisions to help manage the flow of workers, people, assets, and goods with a new level of situational awareness.

Digital twins can even be applied at the individual building level. Many cities and companies are now deploying floor-aware maps for operations and maintenance for better facility management.

No matter the size of the entity being mirrored, digital twins built with GIS continuously respond to incoming data. They can also integrate data not specifically linked to a city. For example, how a weather front moving in triggers scenario planning and preparedness, adjusting schedules and shifting the mission to meet the disruption.

Digital twins can also be considered 4D models. In addition to serving as a constantly evolving document of the present, they can analyze incidents across space and time and model the future. ■

CASE STUDY

ROTTERDAM

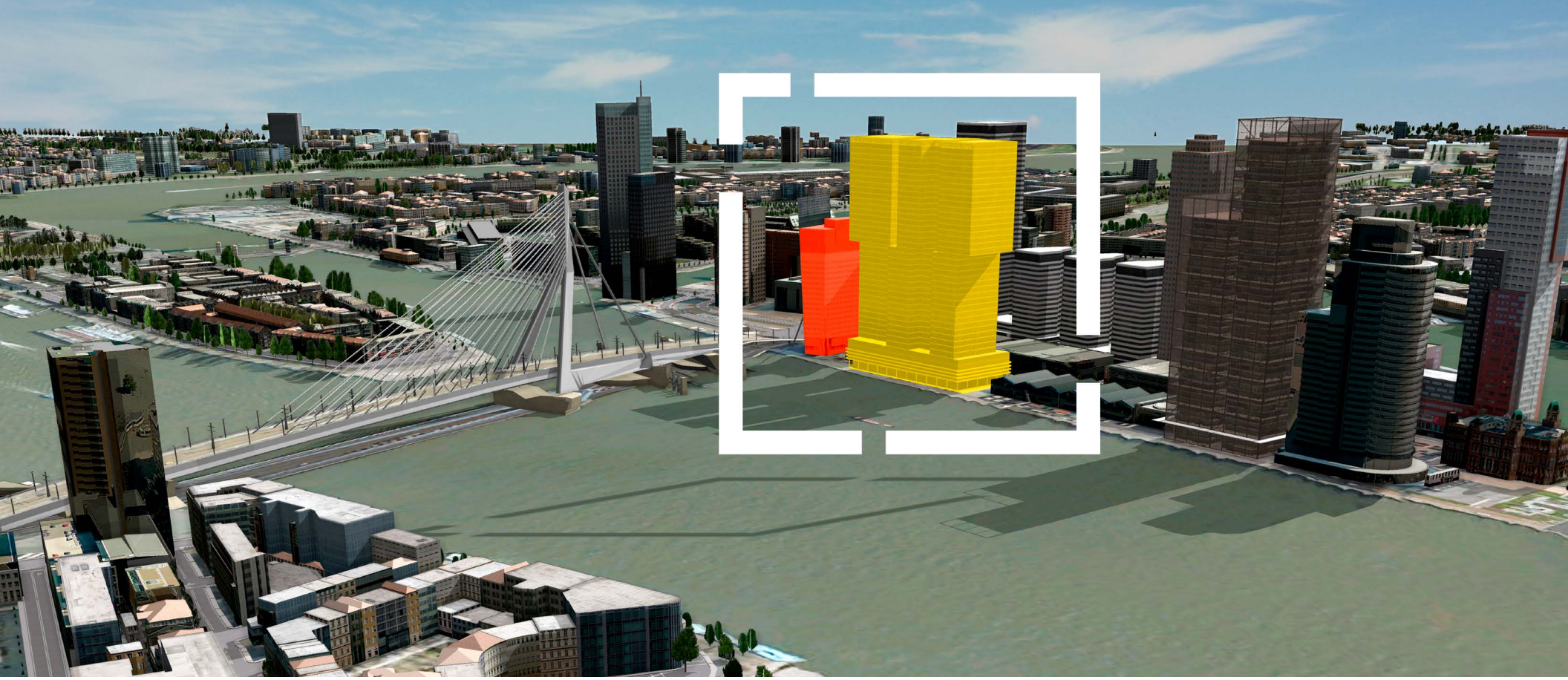
Port of Rotterdam's Use of a Digital Twin to Ensure a Resilient Future

The Situation

The Port of Rotterdam handles the most commercial shipping traffic in Europe—more than 461 million tons of cargo and 140,000 vessels docking each year. Perched on the North Sea and stretching 27 miles inland along the river Meuse, the port is a primary gateway to more than 500 million Europeans. More than 90,000 people work at the port to get its work accomplished. When the port's antiquated software couldn't keep up with the accelerating pace of operations, port administrators went looking for a new system to improve usability and get all departments connected and on the same page.

The Challenge

In 2013, the Port of Rotterdam set a goal to grow the amount of cargo it handles from 400 million tons per year to 750 million tons by 2030. The port has no physical space to expand, so it needed a way to increase efficiency in the existing space. By 2030, the first fully autonomous ships will sail into the port. Shipping containers themselves are becoming intelligent, with sophisticated sensors and geolocation mechanisms. The port's legacy system couldn't connect to other business systems, and its limitations were even hindering the growth of the port because it couldn't handle the space and resources efficiently or intelligently. Over time, the port had amassed 1,500 layers of geospatial data, which posed some system migration challenges. ▸



Rotterdam (continued)

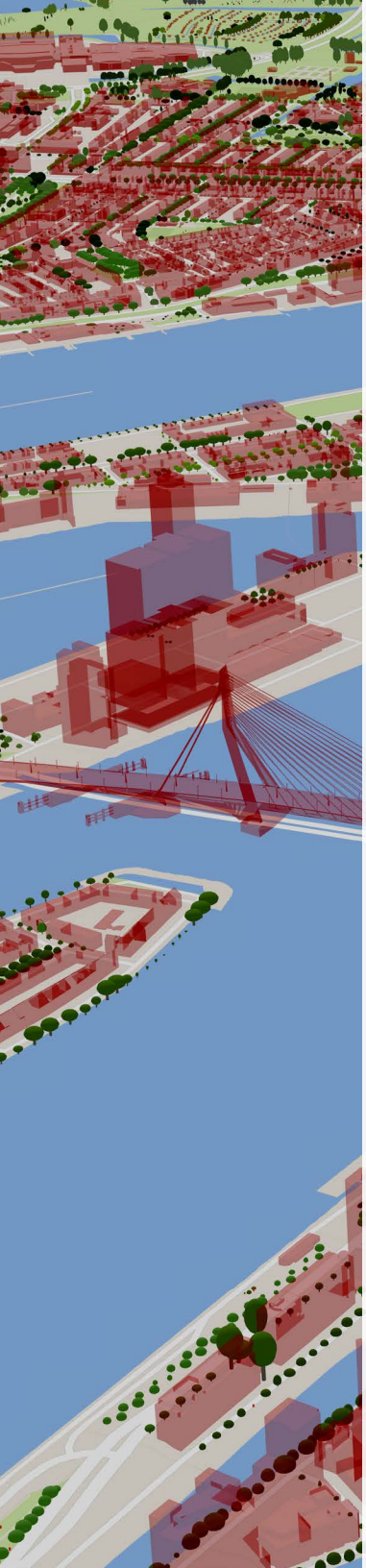
The Solution

PortMaps gives all port employees access to a detailed, map-based system where they can see all layers of information—from all key business systems—overlaid on a high-resolution map of the port. All departments can share their information with this resource, which anyone can access on mobile devices.

The digital twin of the port plays a central role in all manner of operations, including environmental management, security, area planning, port development, maritime traffic control, and incident response. Vehicles and other assets can be tracked and monitored, along with associated assets such as the contents of a container.

The shared map simplifies staff work by centralizing input from many popular work and asset management systems in one shared system and by giving everyone the ability to see what is occurring where.

Previously, the various systems used to manage operations could not easily talk to each other. The port's digital twin, at its core, is a fairly simple map. Underneath the skin of the map lie terabytes of integrated big data—all accessible with three mouse clicks or fewer—along with connections to SAP, Microsoft Office, and a document management system. In the new digital viewer, users can select any area in the port and access live information from SAP and the document management system. ▶



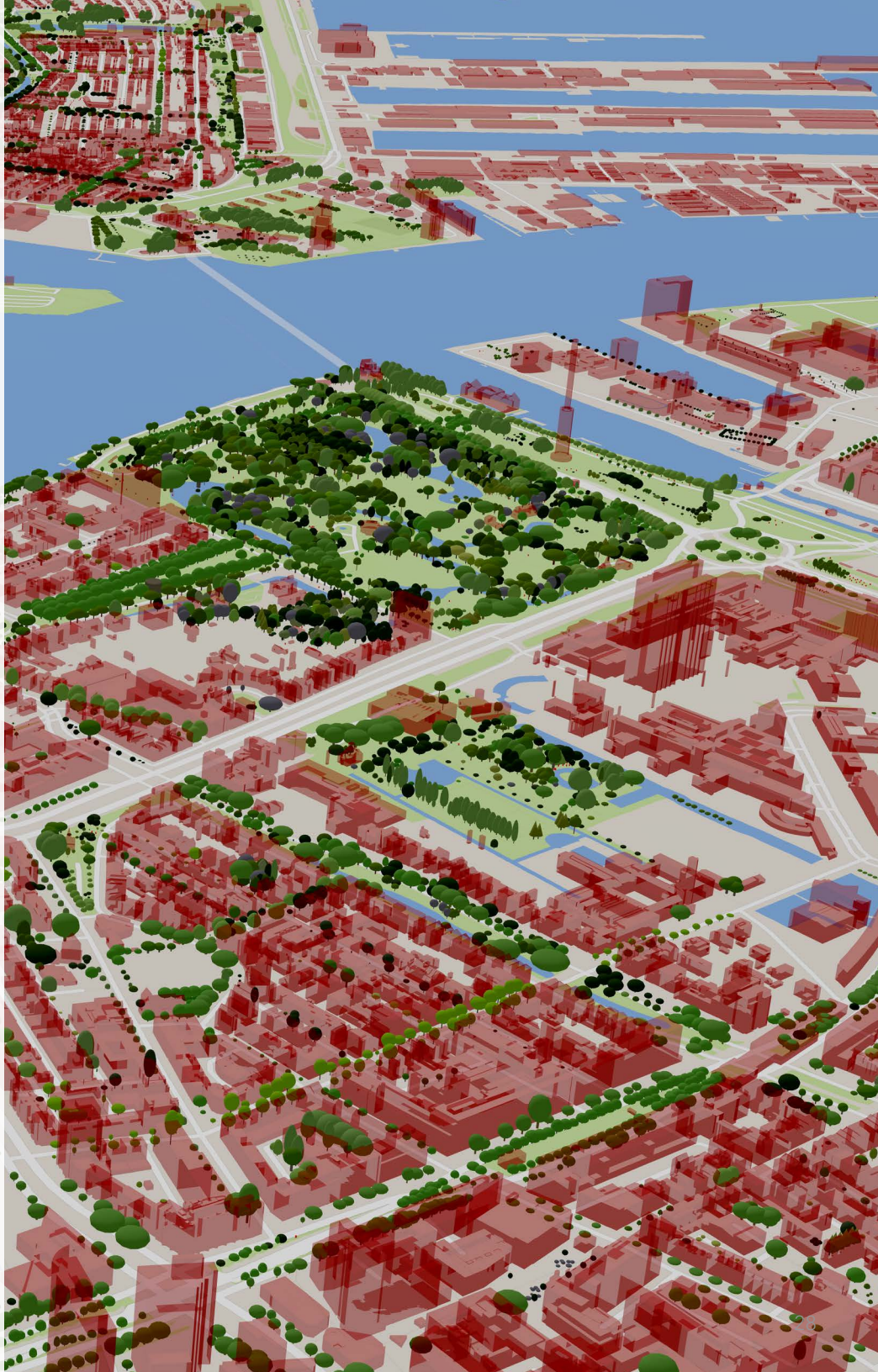
The Results

Today, all Port of Rotterdam data is presented visually on a map. 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.

The new approach allowed the port to phase out 49 systems and centralize access to asset information and administrative records and finances, with overlays of maps. That gave everyone involved with operations the same picture at the same time—the canvas on which to build the port's digital twin.

Rather than working with spreadsheets and lists, a business manager can pull up a lease expiration map; quickly see what areas are occupied, reserved, or free; and view the details of existing contracts.

Since implementing the new system, the port has seen the amount of throughput increase to 461 million tons, a 15 percent increase since 2013. Thanks to real-time information about infrastructure, water, air, and more, the port has improved its service delivery and increased customer satisfaction. And now the port is preparing to make the leap to autonomous shipping. ■



SECTION 6

ACHIEVING EQUITY AND RESILIENCE

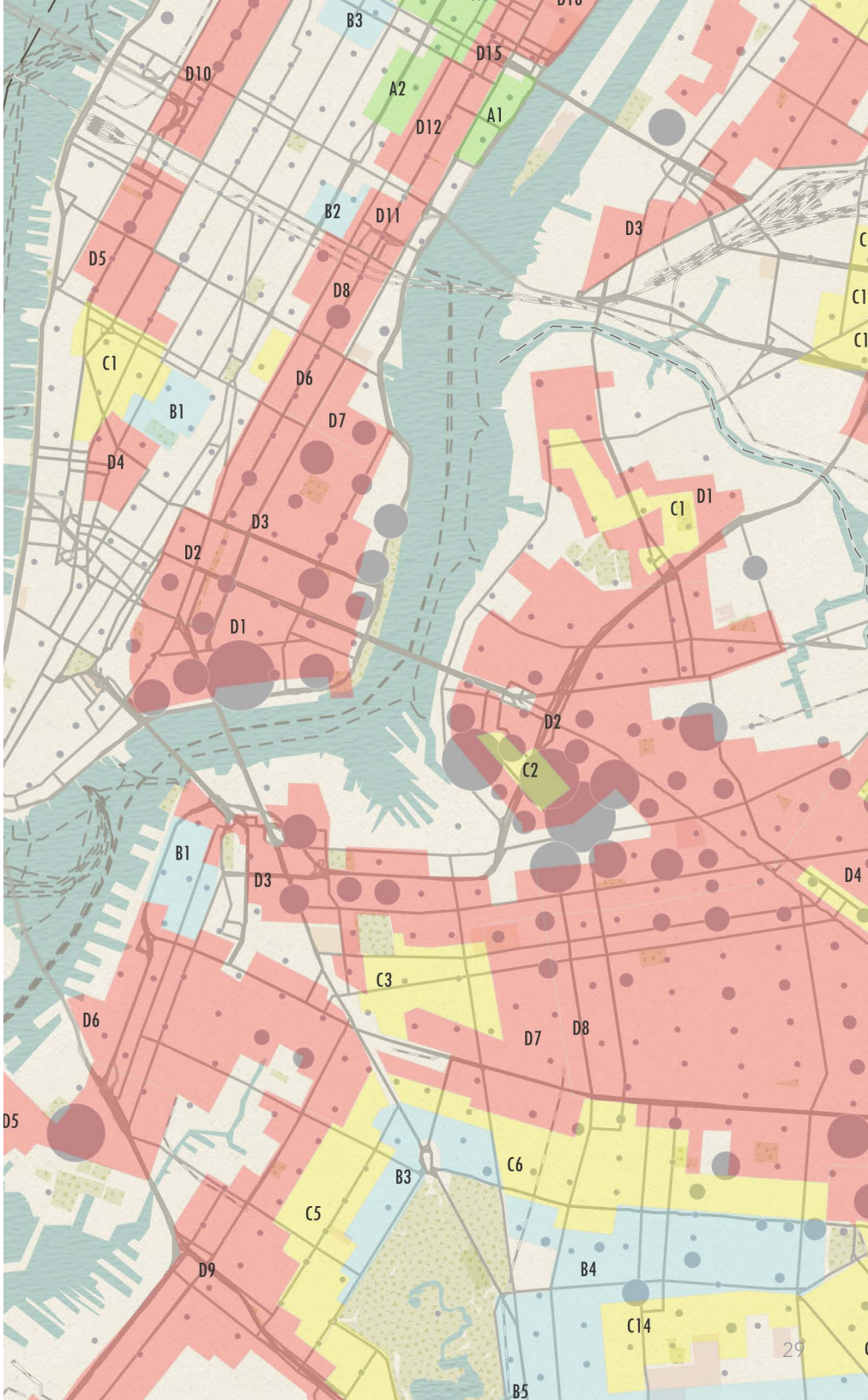
In many ways, geography has been a tool for the greater understanding of inequities, but it has also been the means to draw lines that keep communities segregated. A long history of place-based social exclusion, manifested in practices of redlining, created patterns in cities that continue today. The charge now is to address the underlying causes of increased poverty and inequities.

Many cities are tackling systemic racial and economic discrimination by examining their own past practices and how they allocate funds, services, and resources to make sure they deliver operational excellence for all people.

Supported by data and a map-based awareness of inequities, meaningful reform can happen.

Examining patterns of service delivery often reveals that disadvantaged areas are underinvested in. Reexamining data through a geographic lens has led many cities to prioritize allocations of resources and to improve maintenance to alleviate burdens that have been unfairly distributed.

Using smart maps powered by GIS, cities can examine how current and historical policies and actions have created economic obstacles beyond the control of residents in an affected area. GIS—with its ability to analyze hundreds of layers of factors at once—lets managers and decision-makers look at data on education achievement, financial status, food insecurity, and many other patterns of inequity that all too often match patterns of segregation. ▶



Section 6 (continued)

Researching how the demographics of residents affects their success in life provides a first step and can be eye-opening. When the COVID-19 pandemic hit, the school districts of Palm Beach, Florida, and Philadelphia used GIS to identify families constrained by the digital divide. The school districts delivered computers and Wi-Fi hot spots to enable disadvantaged kids to take online classes. Other cities, like New York City, have uncovered correlations between life expectancy and underserved regions and communities.

Some cities have stood up departments of race and equity that apply an equity lens to every potential project and policy. These agencies use maps and spatial analysis because geography helps governments answer one of the most important questions—Where is the greatest need?

All departments and agencies of city government have a role to play by examining the outcomes of their policies, practices, and procedures for underserved communities. GIS can help identify communities in need as well as the actions required to address disparities.

Esri offers tools and data to map and better understand racial inequity to build a more equitable and just world. Demographic data and historical resources, such as redlining maps, help locate populations of concern, identify barriers to equality, and support informed and equitable decision-making.

Once initiatives and reallocation strategies have been determined, maps and geographic analysis will allow managers to monitor and make meaningful progress with a high degree of precision so it stands the test of time. ■

CASE STUDY

OAKLAND

Oakland's Application of Location Intelligence to Act on Inequities

The Situation

Oakland, like many other major US cities, has a long history of systemic racial and economic discrimination. In the 1960s, community groups founded in the city—including the Black Panther Party, the Unity Council, and the Intertribal Friendship House—fought back. While this activism effort changed many hearts and minds, communities of Black, Indigenous, and People of Color (BIPOC) still face inequities in opportunity and access to city services. In 2015, Oakland became the first city to create a department of race and equity to examine racial disparities and take action.

The Challenge

The three-person team that makes up the Oakland Department of Race and Equity needed a way to quantify the levels of prosperity of the city's diverse population. Staff adopted their director's theory that race matters and that disparities in well-being are largely influenced by race. First, they needed a way to prove the theory, and then they needed to find the barriers and remove them. ▶

Oakland (continued)

The Solution

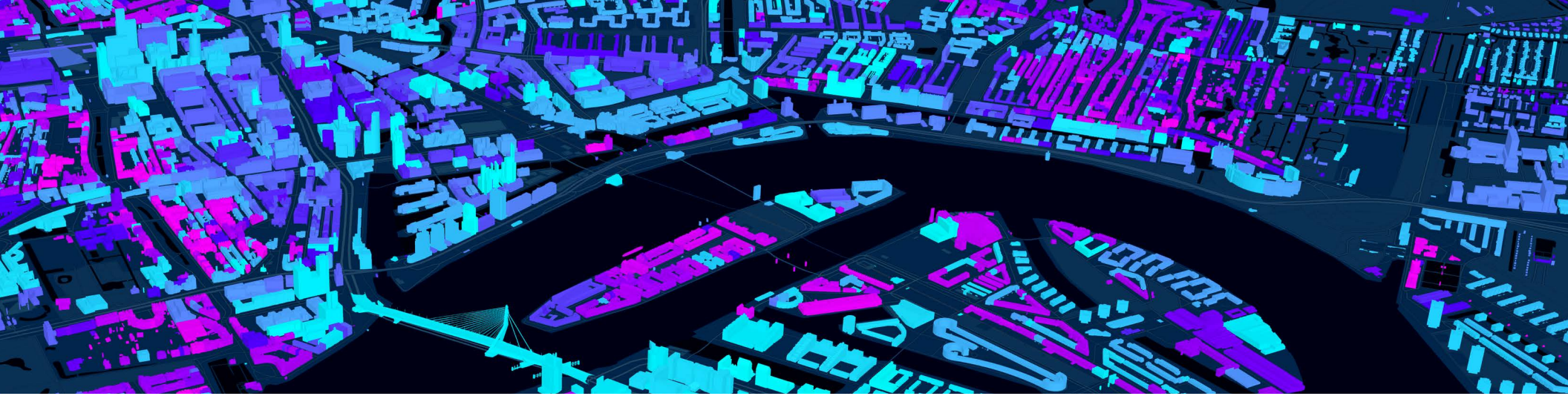
The Department of Race and Equity studied 72 different indicators of well-being, taking data about outcomes and community conditions; breaking the data down by race; and analyzing it in the context of housing, health care, and other concerns. Staff used GIS to organize and analyze existing datasets in order to examine the disparities between the most and least disadvantaged groups across geographies and within six themes associated with the standard of living: economy, education, public health, housing, public safety, and neighborhood and civic life. The output of that work was the *2018 Oakland Equity Indicators Report*.

On its own, presented as charts, graphs, and tables, the data was powerful and informative—but showing it on a map made it intuitive, bringing real experiences with inequities to light.

The Results

When circulated through communities, the map helped people understand the long-term urban effects of structural racism. Just as importantly, it helped spur solutions.

When the Oakland Department of Transportation collaborated with the Race and Equity department on an equity-focused road-paving plan, maps helped staff prioritize which streets to include. Travel data, shown on a map, provided clear evidence of how improving roads in communities of color would positively impact the lives of the most Oakland residents. Using the map was a way to argue for equitable distribution of resources. It helped mitigate the advantage that areas of power and privilege have in decisions regarding civic projects. ■



CONCLUSION

The information flows that are possible today are transforming operations in some of our most complex organizations and places. Cities are embracing a new level of operational intelligence to manage complex international events, ranging from the Super Bowl to the Olympics. Ports and airports are using map-based awareness to share details on incidents and coordinate the work across departments. Transportation agencies, including Transport for London and the Pennsylvania Turnpike Authority, are using real-time awareness to improve the flow of traffic. All of these organizations use GIS to integrate business systems, streamline workflows with location-aware apps, and improve timely decision-making with a digital twin.

Advancements in field data collection and mobile devices, drones, sensors, and the IoT have greatly increased the flow of data. Native cloud technologies and machine learning algorithms process the data as it comes in to signal changes and direct attention to priority incidents. The data flows to apps and dashboards to give everyone a real-time view of assets and people, displayed on a shared map. All the field staff have an awareness of what to look out for, and they can lend their creativity to troubleshoot any situation alongside their peers. Workflows have been improved, with a unified map for all departments.

GIS continues to advance, with streaming real-time data giving an up-to-the-moment view of reality, detailed realistic views that greatly speed understanding and wayfinding, and summary views of historical patterns and trends. A growing suite of spatial analysis tools allow organizations to dive deeply into every incident to answer the *why*, the *so what*, and the *now what* questions quickly.

Cities can learn many things from organizations whose primary goals focus on keeping commerce, goods, and the big game rolling. But cities have a lot to share, as well, when applying operational intelligence to create a more equitable future. The hope for and promise of an operational intelligence system are centered on the idea that sharing information about people, assets, and incidents on a common map ensures that everyone and everything will be seen and factored into decision-making.

GIS makes it easier to tackle and understand challenging missions and topics. By applying it in operations, the data gets better, the root causes and places to invest in become apparent, and the analysis and communication necessary for success on a daily basis become clearer. GIS enables a common view and a way to share data and input from anyone—staff, management, executives, stakeholders, the public, businesses, community organizations, and other government agencies. With shared operational intelligence, we all see the problem in its totality, collaborate to find ways around obstacles, streamline workflows to enhance efficiency, and create a path to effect continual improvement and positive change. ■

Learn More

Esri, the global market leader in geographic information system (GIS) software, location intelligence, and mapping, helps customers unlock the full potential of data to improve operational and business results. Founded in 1969 in Redlands, California, USA, Esri software is deployed in more than 350,000 organizations globally and in over 200,000 institutions in the Americas, Asia and the Pacific, Europe, Africa, and the Middle East, including Fortune 500 companies, government agencies, nonprofits, and universities. Esri has regional offices, international distributors, and partners providing local support in over 100 countries on six continents. With its pioneering commitment to geospatial information technology, Esri engineers the most innovative solutions for digital transformation, the Internet of Things (IoT), and advanced analytics.

Visit us at esri.com.

G1604289