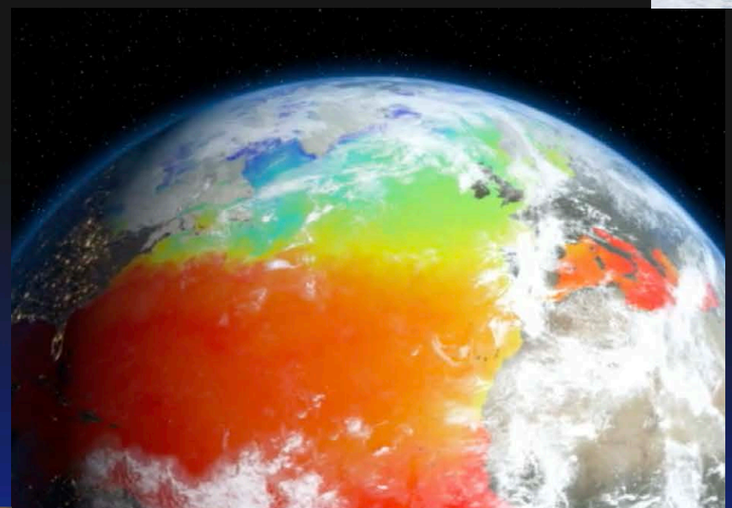
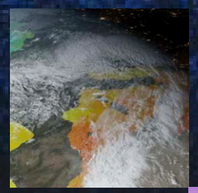
the science of

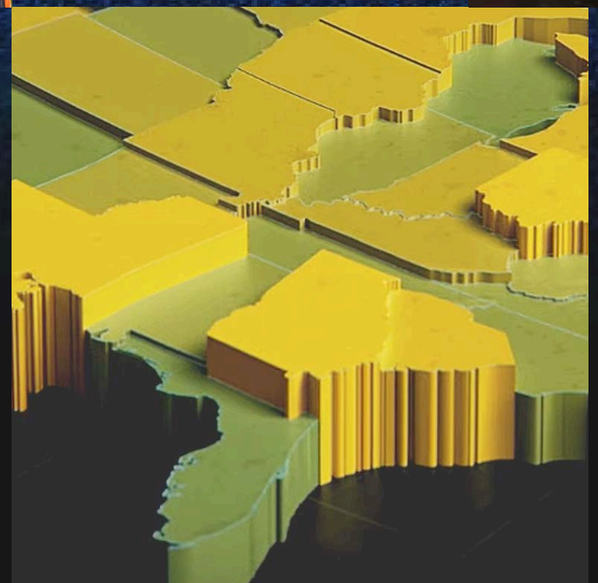
where

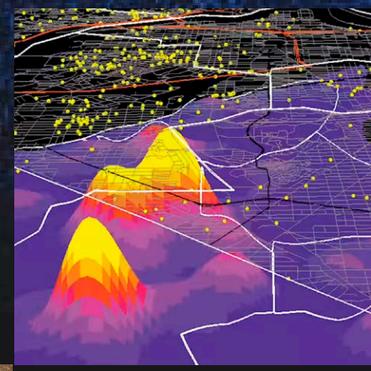
LOCATION INTELLIGENCE

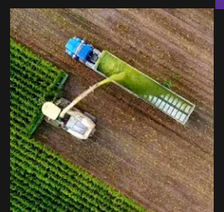
Insights That Transform Decision-Making

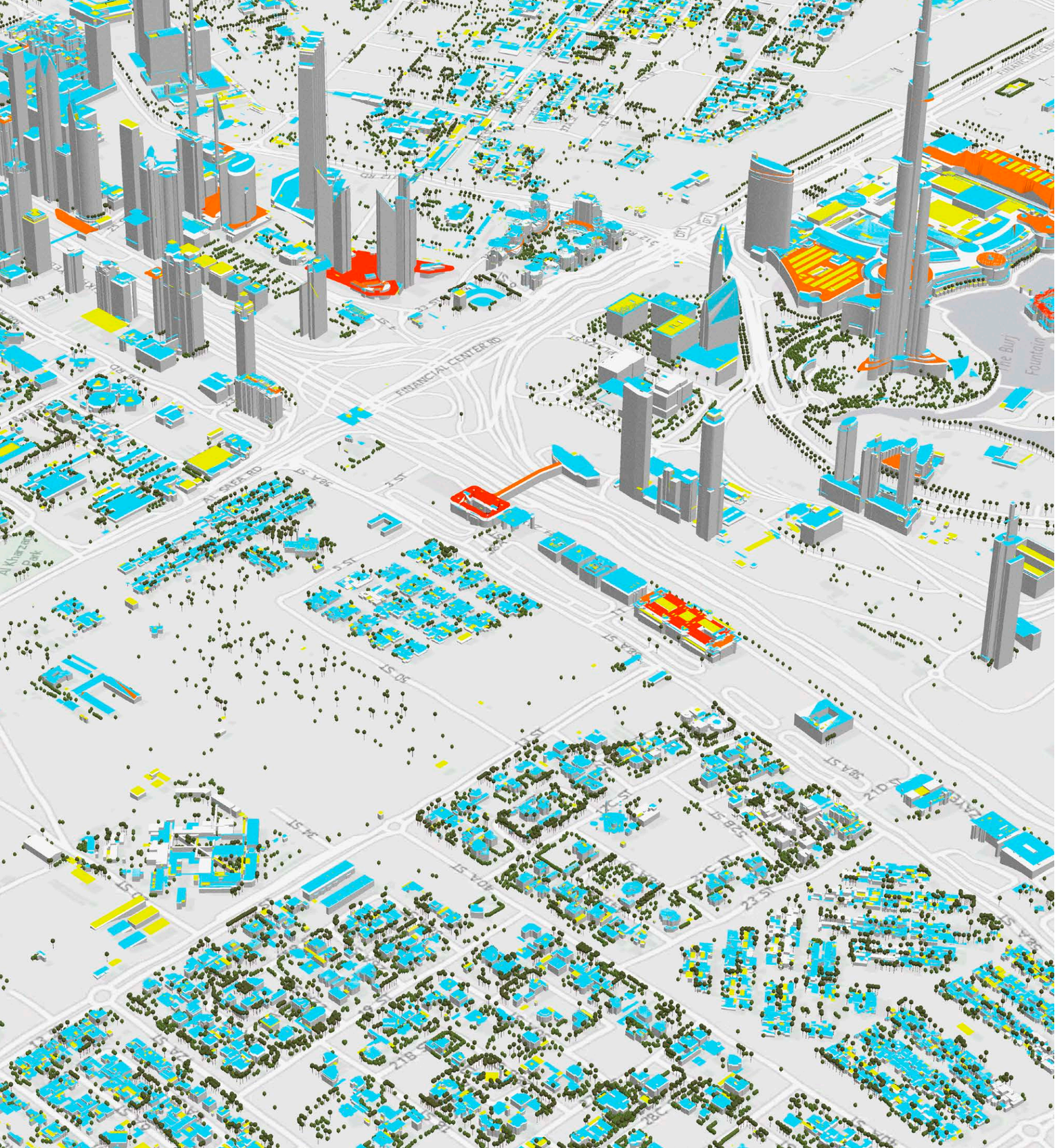












LOCATION INFORMATION HAS ALWAYS BEEN IMPORTANT. NOW WITH BILLIONS OF SENSORS AND SMART DEVICES, WE HAVE MUCH MORE OF IT. AS THE VOLUME AND DIVERSITY OF DATA EXPANDS, SO DOES THE NEED TO VISUALIZE AND ANALYZE IT.

LOCATION INTELLIGENCE

Seeing Opportunities for Business Growth in a Deeply Connected World

For decades, many business leaders have understood location to be foundational for operations and growth. In recent years, the importance of *where* has grown exponentially. The reason is simple. As the volume and speed of data become greater, the location component becomes more and more vital to maximizing data's value.

There may be no clearer example of the power and the importance of location intelligence than the COVID-19 pandemic. With iconic map-based dashboards, the pandemic showed that geography—location—is *the* framework we need to make sense of the complicated world we've created. Further, the pandemic underscored the importance of geography to core business functions like supply chain and risk management. Location adds crucial context. It enriches all types of data and helps tell the story of what's happening and why.

Location intelligence refers to insights gained from visualizing and analyzing data in terms of its geographic location—on a map or dashboard. Organizations generate location intelligence by using spatial analytics to detect and quantify problems on an enterprise level, make predictions, model solutions, and strengthen their business operations. Organizations can then answer a question that has enormous value: Why do things happen where they do?

Geographic information system (GIS) technology gives data a physical presence on maps, allowing organizations to add layers of relevant information to derive more meaning—like layering demographics, traffic, environment, economics, and weather to see trends and patterns of change. This is a powerful way to organize information from disparate sources. ▸

LOCATION INTELLIGENCE, WHEN DEPLOYED ON AN ENTERPRISE LEVEL, EMPOWERS AN ORGANIZATION TO DRAW CONCLUSIONS, MAKE CONNECTIONS, AND SEARCH FOR HIDDEN TRUTHS.

A common estimate of the amount of data in the world with a location component is 80 percent. That's why geography provides a powerful way of bringing all that data together to understand relationships and impacts.

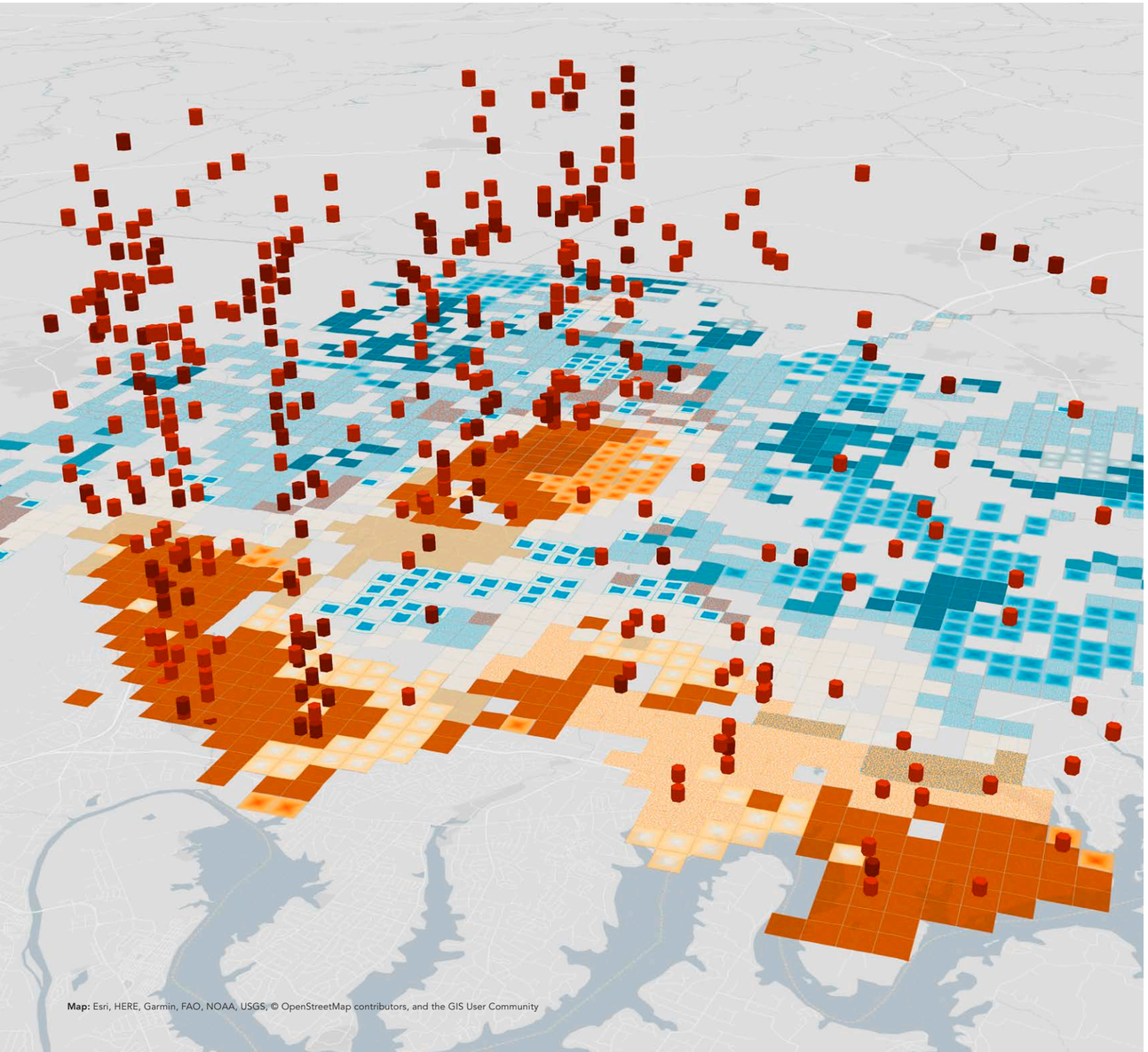
Location intelligence offers more than a way to think about data. It provides a way to organize, rearrange, and examine data from all angles to find the connections and hidden truths within.

If location intelligence is the objective, GIS is the most valuable tool to achieve it. GIS is what businesses looking for an advantage use to decide how best to move forward—determining, for instance, where to open a new store, how to manage assets, and how to mitigate risk and plan in an era of climate change. These are diverse problems, but they have two things in common: involvement with the question of *where*, and the need to process an enormous amount of data to find an optimal solution.

GIS was once solely the purview of geographers and mapping experts, but no more. User-friendly interfaces and cloud-based tools make location intelligence something that anyone can grasp and access. Information can be organized via the familiar visual vocabulary of maps. Dashboards allow for easy handling of data and gathering of statistical inferences from embedded maps. Enterprise-level GIS empowers organizations to share and collaborate with real-time maps, exponentially increasing the possibility of useful insights.

GIS is used to build billions of sophisticated maps and models, combining big data, artificial intelligence, and an ecosystem of apps to bring a location-based approach to the world's thorniest problems. ▸

THE CONTRIBUTION OF LOCATION INTELLIGENCE TO FUNDAMENTAL BUSINESS OUTCOMES IS ONE REASON WHY THE LI [LOCATION INTELLIGENCE] MARKET WILL BE WORTH $36 BILLION BY 2028, MORE THAN TWICE THE VALUE IN 2021, AND IT'S GROWING AT A RATE OF 15.3 PERCENT PER YEAR.



Map: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

The Business Value of Location Intelligence

It has often been asserted that data is the new gold, but that analogy falls short. There is no question that data is linked to information, information produces insights, and insights are what give an organization an edge over competitors. But gold is rare, and data is everywhere.

With so much data, organizations need a way to quickly filter it for what they need. They need good data—the kind that provides value reliably. GIS is both a creator and a consumer of good data, with tools to store, process, analyze, and visualize data.

Although GIS is often described as a mapping tool, the technology does much more than make maps. GIS provides a way of seeing the interconnectedness of our world's systems—both natural and human made.

This is the essence of a geographic approach–the understanding that everything is related to everything else–and that is why it holds power for any organization. GIS is about finding those connections and uncovering the location intelligence.

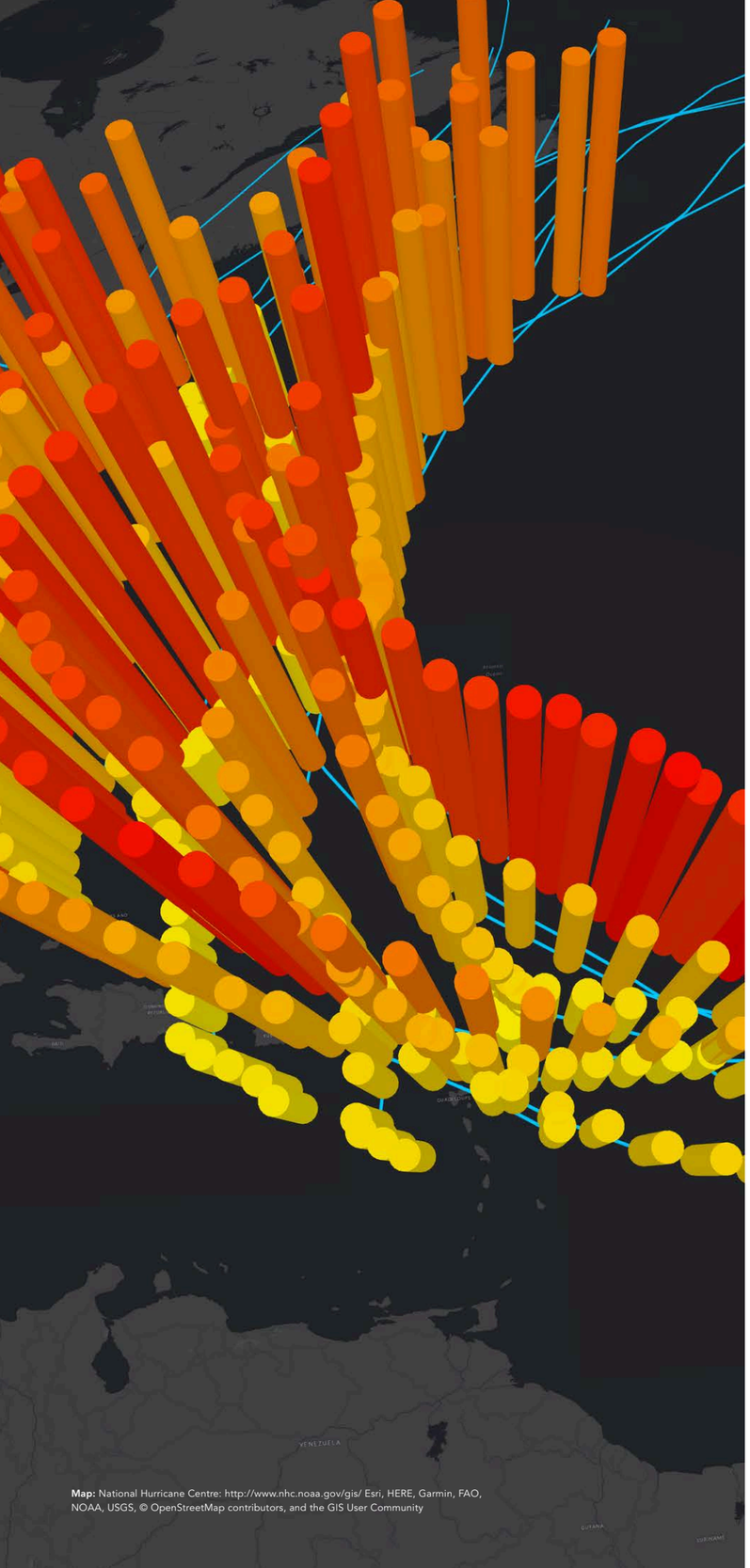
This geographic approach took a huge step into mainstream consciousness during the COVID-19 pandemic. The Johns Hopkins University COVID-19 Dashboard attracted billions of users because it provided an information lifeline. The maps and graphics displayed on the dashboard gave people around the world a way to see and understand the complex health crisis as it evolved in real time.

GIS has evolved to integrate other technologies, such as connecting financial, customer, and operational systems to unite the different types of data on a map. GIS also brings together building information models, CAD drawings, and reality-capture data to create dynamic digital twins that display spatial relationships. Geospatial artificial intelligence (GeoAI) brings together GIS and machine learning with algorithms that discern patterns and hot spots. ▸

Venture capital funding is now fueling geospatial analytics, with US-based startups in 2020 receiving $2.5 billion in funding—a 25 percent increase over 2019, according to Deloitte.

C-suite executives across diverse sectors are reaching the same conclusions regarding the power of location intelligence. A recent survey conducted by Boston Consulting Group revealed a nearly universal respect for the value of location intelligence. In financial services, retail and e-commerce, logistics, real estate, and travel and tourism, nearly all respondents asserted that location intelligence is very or somewhat important to their business. Another survey, by Dresner Advisory Services, found that across companies, three enterprise areas—R&D, operations, and executive management—were most likely to recognize the importance of location intelligence.

The reasons for enthusiasm are easy to understand and not limited to market competitiveness. As the world grows more volatile and complex, challenges such as climate-related weather events, health crises, geopolitics, shifting regulatory regimes, the need for environmental management, and supply chain turmoil underscore the importance of geography and location intelligence. GIS delivers the contextual awareness leaders need to mitigate risks and achieve long-term sustainability as well as profitability. In simple terms, location intelligence pays huge dividends to understand—ahead of competitors—*where* things happen and *why*. ▸



Map: National Hurricane Centre: http://www.nhc.noaa.gov/gis/ Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

The Many Applications of Location Intelligence

The applications of location intelligence are broad, especially when applied on an enterprise level and supported by real-time data. The former ensures that an entire organization both contributes to and benefits from location intelligence. The latter ensures that decisions are based on the most current information.

Consider the advantages for **supply chain optimization**, as businesses in the postpandemic world strive to maximize logistics and work around supply chain disruptions. A major US agricultural company can track the location of each truck, its temperature, and its trajectory, reducing costs due to spoilage. The same company can use location intelligence to understand why, for example, a particular batch of strawberries was superior. The company can see where that batch came from, right down to which part of the field. Staff can then analyze what was different about conditions in that location in order to repeat the success in the future.

The ability to **precisely track the origin** of every crop or commodity is taking on greater importance. Knowing which field, what farming practices, and the progress of the crop helps the timing of the supply chain. It also allows the company to be proactive if issues arise. For forestry products that may harm rain forests, certified sustainability practices and material source knowledge have become a business imperative, supplied by location intelligence.

Consider the prevalence of extreme weather events, such as hurricanes, which will continue to worsen as climate change intensifies. A large weather event's ripple effects can enormously impact residents, international supply chains, and retailers. With location intelligence, organizations can **proactively approach a major climate event** by using analysis to mitigate damages and make strategic decisions.

Imagine a logistics company with a cargo ship scheduled to pass through the Suez Canal just before a storm is predicted to make landfall. Analysis of real-time data feeding into GIS empowers company leaders to react strategically and nimbly. By accounting for information from many data layers at once, they can make quick decisions to minimize supply chain impact.

Location intelligence allows government and disaster relief agencies to prepare for the same storm and respond efficiently after it hits. By modeling and tracking storm surges and water flow with GIS, agencies can predict which areas will be hardest hit, informing evacuation plans and allowing predictive and reactive aid.

As wildfires grow in frequency and intensity, firefighters use GIS to visualize and study the movement of each blaze—communicating that information quickly to everyone involved. In the fire's aftermath, land management agencies look to GIS to determine best practices for replanting trees and restoring habitats.

Many organizations integrate location intelligence into their day-to-day business operations, particularly in the form of **location-aware digital twins**. In Australia, one of the largest energy companies built a digital twin that contains over 24 million features, from substations to the point of entry into the home. Field crews working in remote locations can search the digital twin for assets in the network, zoom in, access information, and trace the connectivity to the power source and the customer service point. ▸

The energy company is using its digital twin to deal with increasingly common floods and fires. Staff plot data from past events, show affected areas on a map, and then anticipate which assets will be endangered in the future. In this way, GIS models the past, present, and future to provide location intelligence through space and time.

A major work clothing manufacturer redefined its business to accommodate the changing habits of customers, using location analysis to **assess new markets and understand consumer behaviors** across channels. The manufacturer's location intelligence powered a road map to selling goods at brick-and-mortar stores and via wholesale distributors, retail partners, and e-commerce sites.

The single-pour coffeemaker company Nespresso uses location intelligence along multiple business vectors, including a sustainable coffee growing program, reforestation, and aluminum recycling. With more than 75,000 farmers growing the company's coffee, and with customers around the world, Nespresso leaders recognize location intelligence as crucial to synthesizing their overall growth strategy.

Governments have long been GIS users, but today, many agencies are applying location intelligence in innovative ways. Take, for example, CalFresh, California's version of the federal Supplemental Nutrition Assistance Program (SNAP). Leaders in the California Department of Social Services began examining technology applications popular in the business world to improve the lives of constituents. As a result, CalFresh now uses location intelligence to identify potential enrollees who are not taking advantage of public services. By using heat maps that incorporate demographic data, CalFresh staff can see previously hidden patterns, such as the migration of poverty into suburban areas.

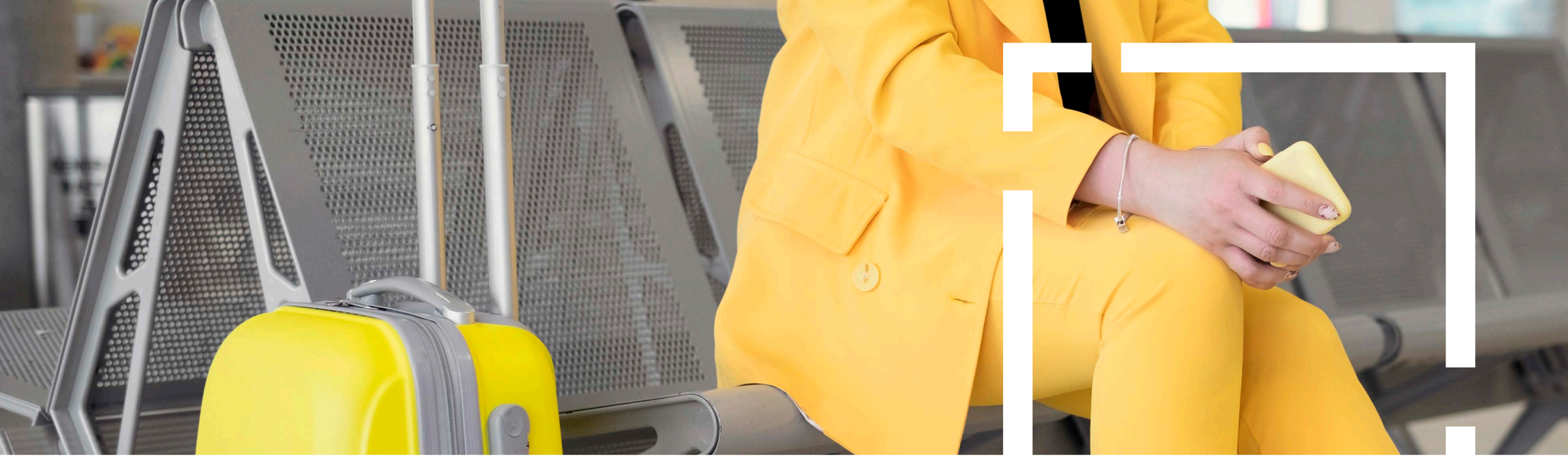
A truly location-intelligent organization empowers everyone to **create, manage, and share location-based information**. Mobile utility crews, for example, can use a smartphone or a tablet to securely send and receive inspection and maintenance updates to and from the office. Managers can monitor the progress of their personnel. Customer service agents can see what's going on in real time to provide customers with information about outages and repairs. Executives and accountants can visualize and analyze the entire system before deciding where to prioritize infrastructure funds. ▸

BUILDING DATA SCIENCE CAPABILITIES AROUND LOCATION INTELLIGENCE HELPS BUSINESSES SEE THINGS FROM A DIFFERENT PERSPECTIVE, TO THINK ABOUT THE JOURNEYS OF PRODUCTS AND CUSTOMERS THROUGH DATA.

The Geography of Data Science

These examples of a geographic approach to problem-solving only scratch the surface of what location intelligence offers organizations across retail, manufacturing, supply chains, utilities, insurance, telecommunications, banking and financial services, government, and logistics.

Increasingly, location is the key to unlocking hidden and valuable insights within data—to make decisions that improve customer experiences, create operational efficiencies, and increase productivity. Seeing relationships between and among data points and translating those relationships into actionable information are critical to maximizing the value of the data pouring in. ■



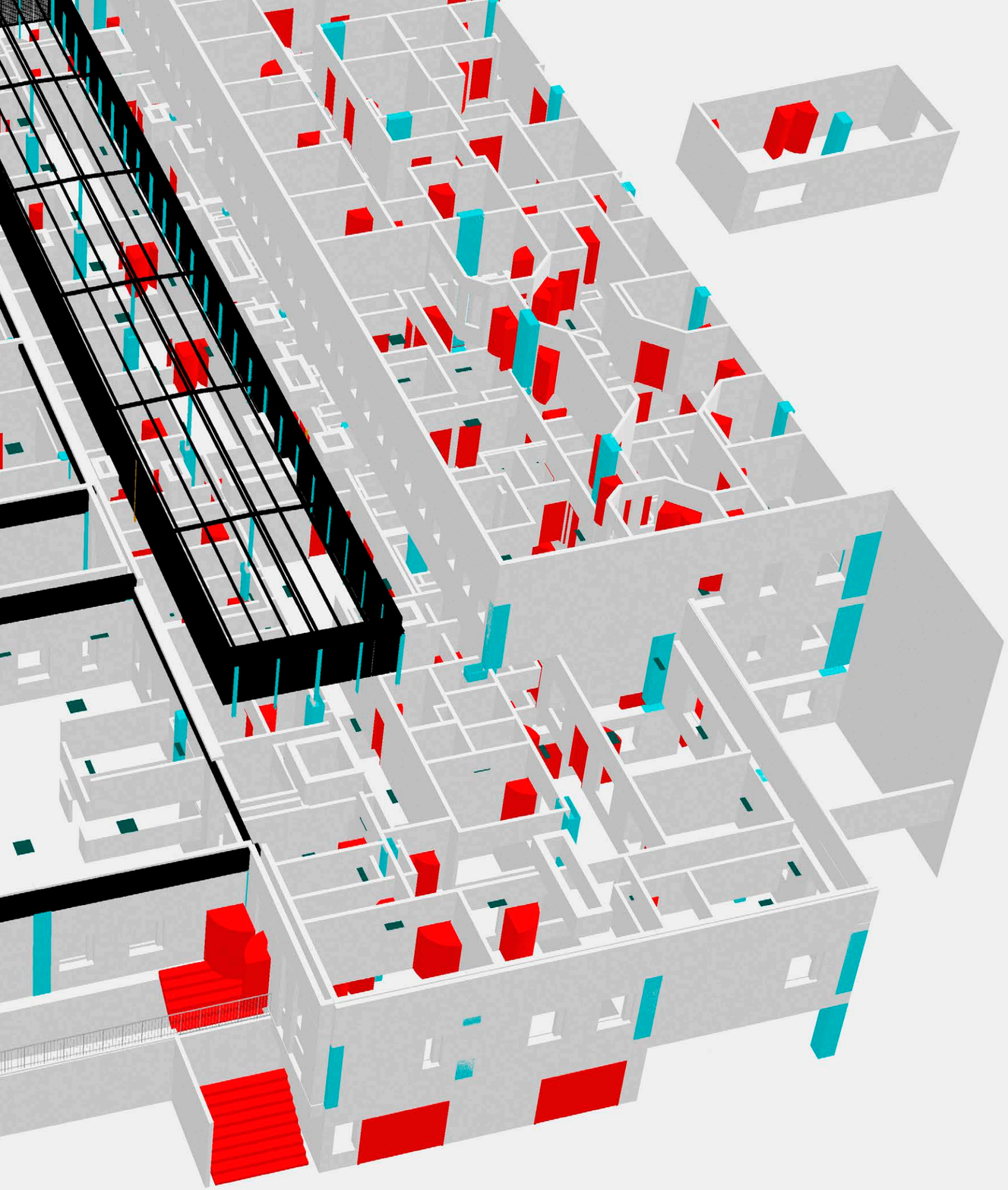
LOCATION INTELLIGENCE MOVES INDOORS

Apple

It's estimated that most Americans spends 87 percent of their life indoors. While our trusted GPS-equipped mobile devices help us navigate almost anywhere outside, they lose accuracy once we go indoors.

Indoor mapping, or the lack thereof, is often a challenge for people who need to move around a facility like a hospital, convention center, industrial plant, corporate or university campus, or airport. There is a growing demand for maps that show a person's location in relation to the inside of a building, helping them locate, for example, an available conference room or a high-pressure valve that needs immediate inspection.

To have truly effective location intelligence, an organization needs more than an indoor map. People need indoor positioning to see their current location—that "you are here" blue dot—in the context of nearby people, spaces, and assets. ▸



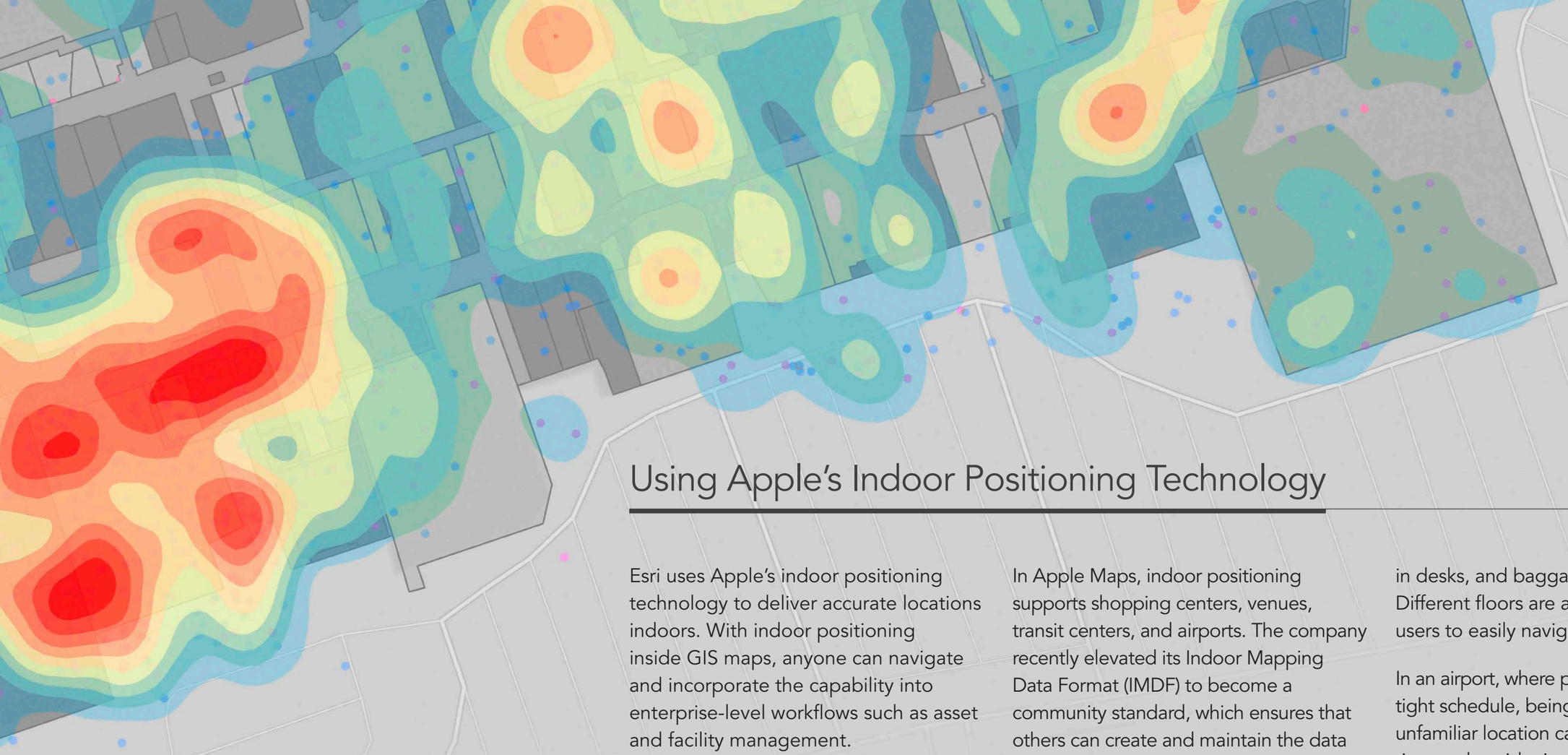
Map: BIM Model by Aripa Arquitectos; BIM - GIS Integration by Esri Portugal

Bringing the Power of Location Inside

Indoor positioning gives employees, customers, travelers, and visitors the ability to see and share their locations in relation to important assets, rooms, departure gates, and offices. This information, combined with navigation, scheduling, and analytics, helps people inside buildings operate at an increased level of efficiency and safety. Using location intelligence tools, indoor positioning enables businesses and organizations to better coordinate spaces and other resources.

From simple mobile apps to complete enterprise systems, indoor positioning adds a new dimension to the application of location intelligence technology.

Managers and executives can take advantage of indoor positioning by accessing interactive dashboards that stream data from sensors inside a facility. Meanwhile, visitors and employees benefit from indoor positioning by being able to use their computer or smartphone to find information about the buildings they occupy. Building operators and occupants can access floor-aware 3D maps to find critical business information such as the location and status of fire extinguishers and their last inspection dates. Enterprise knowledge workers such as maintenance, IT, security, medical, and visitor management personnel are particularly well supported by the emergence of indoor mapping and analytics. ▸



Using Apple's Indoor Positioning Technology

Esri uses Apple's indoor positioning technology to deliver accurate locations indoors. With indoor positioning inside GIS maps, anyone can navigate and incorporate the capability into enterprise-level workflows such as asset and facility management.

With the crucial positioning element developed by Apple, apps with indoor maps and location deliver advances for large venues. In many cases, Wi-Fi location services meet the positioning requirements of an organization without the need to invest in Bluetooth beacons. Maps display both indoor position and floor level, determined using a combination of information coming from the sensors on the iOS device together with information from Wi-Fi signals in the building.

In Apple Maps, indoor positioning supports shopping centers, venues, transit centers, and airports. The company recently elevated its Indoor Mapping Data Format (IMDF) to become a community standard, which ensures that others can create and maintain the data so that indoor maps will proliferate. Apple has also considered the rise of robots. Its IMDF provides machine logic to help intelligent machines make accurate navigation decisions in real time.

The company's pioneering work in indoor positioning is providing visitors and staff with a full layout of each airport or mall. It uses an interactive map to show the location of features such as restaurants, shops, bathrooms, gates, terminals, security checkpoints, check-in desks, and baggage claim areas. Different floors are also marked, allowing users to easily navigate.

In an airport, where people are often on a tight schedule, being able to visualize an unfamiliar location can help travelers save time and avoid missed flights. In the case of a large and complex mall, stores can be filtered by category—clothes, beauty, or food, for example—enabling people to more quickly find what they are looking for.

Many private organizations such as hospitals, universities, and corporate campuses are using IMDF to create and maintain their own maps—because employees and visitors alike benefit from an accurate and up-to-date facility map. ▸

Map: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Putting Buildings on the Map

GIS technology from Esri can create and consume Apple's IMDF. Esri leverages Apple's indoor positioning capabilities to bring location intelligence to enterprise organizations and knowledge workers everywhere. The ability to deliver situational and contextual awareness through indoor maps was important during the physical distancing phase of the pandemic. As working from home has transitioned into hybrid work environments, companies have cut back on physical space to reduce cost and maintenance. The concept of hoteling, with adaptable physical space assigned as needed, requires flexible indoor maps, especially on campuses that require coordination between a large group of employees and buildings.

Indoor mapping technology also helps organizations manage their facilities. Employees can see, for example, the precise location of malfunctioning equipment or be alerted to time-sensitive checks such as changing out filters. Using indoor maps, maintenance personnel know where to go and when to go there.

Security staff also benefit from indoor mapping. With real-time updates, the maps give them the ability to quickly ascertain any raised threat levels and quickly guide people away from danger if necessary.

Indoor navigation is particularly important for large and confusing places like hospitals. Technicians require accurate information about where people and movable assets are located at any given time—such as the proximity of patients to ventilators or expectant mothers to ultrasound machines. In a large medical center with an emergency room or an intensive care unit, finding resources quickly can be critical when seconds count.

The value of indoor mapping continues to compound, empowering managers of large facilities to draw authoritative conclusions about the status of operations, the flow of people, and the locations of resources. At the same time, the technology provides efficient navigation and more effective workflows for visitors and staff. ■

EVs and New Ways of Living

FUELED BY LOCATION INTELLIGENCE

The transition to electric vehicles (EV) represents a long overdue response to the ongoing climate emergency. California, having by far more registered cars than any state in the nation, has pledged to cease sales of new fossil fuel-burning cars by 2035, and automotive companies are increasing EV production.

The Infrastructure Investment and Jobs Act will invest $5 billion to expand EV charging networks across the country. And the Inflation Reduction Act (IRA) lifts the per-manufacturer limit on the number of cars that can receive a plug-in electric vehicle tax credit. A rebate is offered even on used EVs to extend the benefit to all. Given that transportation is the greatest contributor to greenhouse gases, the combined investment and incentives put the United States within reach of its Paris Agreement commitment to cut emissions by half by 2030.

However, these changes also present new challenges. Mining lithium in sufficient quantities to withstand demand for EV batteries is itself carbon intensive and raises concerns over environmental degradation, resource extraction, and human rights. Additionally, EV charging infrastructure remains underdeveloped. Potential EV owners are reluctant to make purchases until charging station networks improve, while private investors that would finance EV infrastructure are waiting for EV production to catch up to demand.

These challenges require insights not only about where best to place new EV chargers but also in regard to broader urban plans and infrastructure practices. EV crossover represents a completely reimagined way for us to move and live. And the push to reduce dependence on fossil fuels is driving a transformation of our transportation infrastructure. Location intelligence provides the means to examine these complex issues and achieve clarity on viable solutions. ▸

Illinois's EVTown Paves the Way for Sustainable Practices

The city of Normal, Illinois, has long seen itself as an important outpost of the EV revolution. In 2011, after enticing Mitsubishi to open a plant to manufacture the i-MiEV—an innovative electric car that proved too early to market—Normal dubbed itself "EVTown."

Mitsubishi's arrival coincided with the city's Sustainable Normal plan, which included new bike trails and walkways, nature-based stormwater solutions, a revamped train station, and investments in renewable energy and EV charging stations.

Six years later, Rivian, an EV company backed by Amazon, bought the former Mitsubishi factory and expanded it to four million square feet with production lines for trucks, SUVs, and Amazon delivery vehicles. The city's commitment to sustainability and transparency was a major factor in the company's decision to build operations in Normal.

To achieve their mission, city planners in Normal rely on location intelligence for making decisions and tracking progress. GIS maps and dashboards enable project visualization and analysis across teams and departments while also facilitating public communication and data sharing.

Residents can also access GIS maps and dashboards online to see the city's project plans and verify that investments are equitable across the city. "The purpose of this tool is to make it easier for the public to know exactly what's going on in their neighborhood," said Vasudha Gadhiraju, director of Normal's Innovation and Technology Department.

For transparency, the city recently extended its use of GIS to Normal's Community Investment Plan. Previously, the plan was posted online in a spreadsheet, a format that was not easy to understand and was time-consuming to update. Now, anyone can easily view the information and examine projects in relation to their geographic location.

Cassidy Killian, Normal's GIS coordinator, oversaw the creation of department-level dashboards. Using GIS, staff across departments can filter their data, record ongoing projects, and find metrics by project type. "The biggest benefit is seeing who is doing what and where, getting that overall picture in one place," Killian said. ▸

Because each department shares its data, staff can identify project conflicts and track funding sources to coordinate project phases. For example, if a water main project has approval, the water department can view the scope and timetable for road improvements at the same location as the project, eliminating the frustration of having to cut into freshly paved roads.

Urban planners are applying their GIS-based planning and analysis to the renewal of the city center, called Uptown Normal. The work started by replacing a dangerous five-way intersection with a pedestrian-friendly roundabout and community plaza known as Uptown Circle. The traffic-calming effect has made Uptown Normal a more attractive setting for businesses and housing, increasing property values while triggering new investment.

The city also created a GIS-powered business directory that shares Uptown Normal's dining, shopping, entertainment, and lodging options—useful to visitors, residents, and the 21,000 students at Illinois State University. The directory automates the business licensing process, drawing data directly from each company's required submissions. If a business is not on the map, its license isn't current.

As part of its sustainability commitment, Normal uses location intelligence to identify projects that promote active and multimodal transportation. Projects include the extension of a trail network to new suburbs and the expansion of the bike trail along historic Route 66 that links the town to five other communities. And the new Uptown Connector Underpass will provide pedestrian and bicycle passage beneath the railroad tracks, increasing access to railway platforms and enhancing safety for high-speed trains. ▸

The Ray:
Solar Power Arrays along US Highways

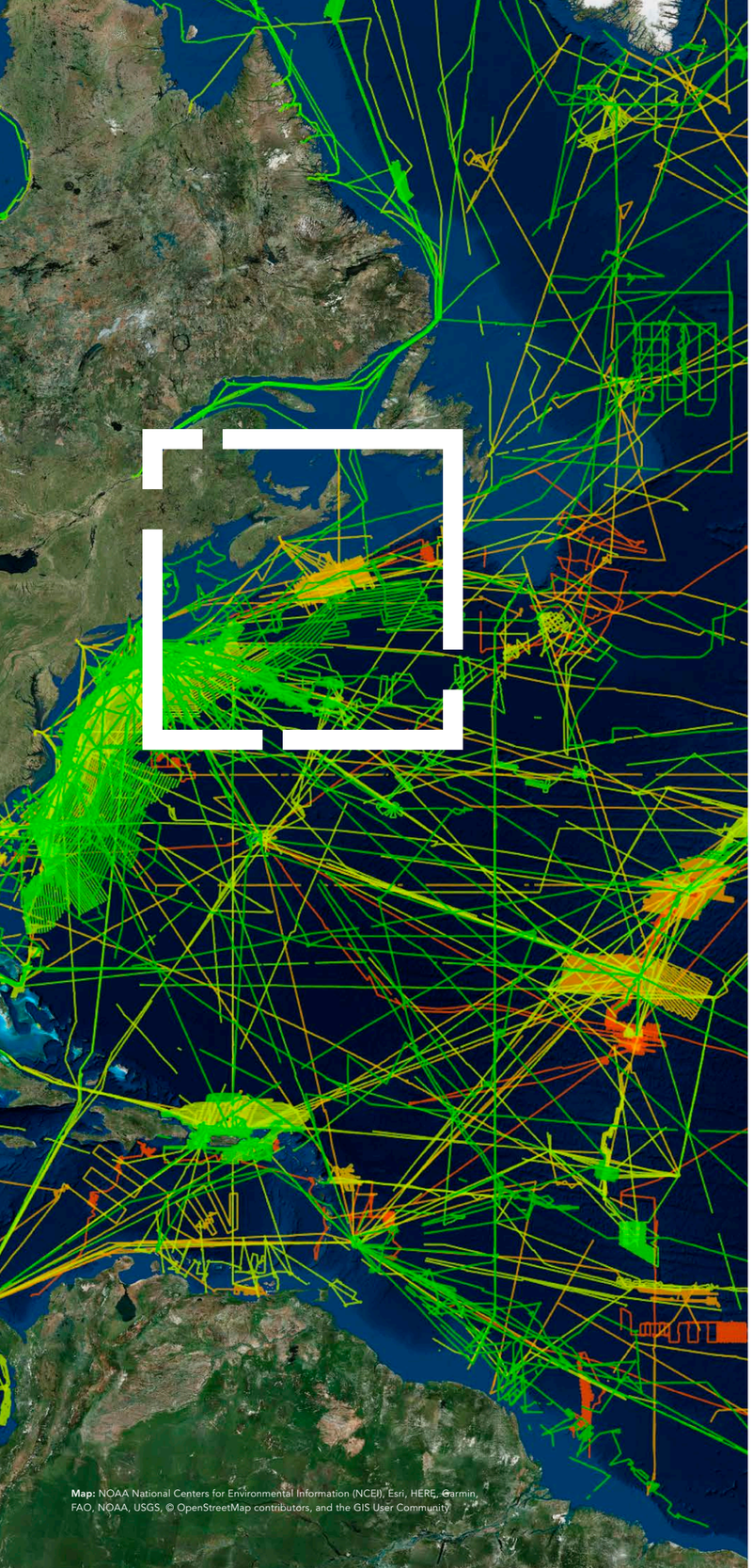
The need for sustainability forces us to reimagine land use and resource allocation. The Ray, an Atlanta-based nonprofit, promotes a renewable energy purpose for land that is usually considered little more than a blank space along the nation's highway system.

A highway right-of-way (ROW) is a buffer space—including shoulders, medians, rest stops, and turnoffs—that provides breathing room on high-speed thoroughfares. Most ROW land is shade free, which makes it an attractive location for generating solar energy.

The Ray works with state transportation departments to install solar arrays on ROW spaces. Georgia, Iowa, Oregon, and Massachusetts are among the states that have launched pilot projects. The company's estimates indicate that many states have enough federal interstate freeway ROW land to support thousands of acres of solar arrays. The acreage around interchanges alone could generate 36 terawatt-hours of electricity, enough to fully charge 12 million EVs each year.

Locating suitable ROW land is no easy task, however, due to stringent requirements. The Ray uses a GIS tool with formulas and decision trees that help transportation engineers find ideal spots for solar arrays.

In Iowa, The Ray recently worked with planners to analyze site suitability on 238,000 acres of ROW land. Considerations included a rule that no array could be more than five miles from an electrical transmission line. The first step was to take a basemap of Iowa and overlay a data layer of transmission lines, with a five-mile buffer on either side of every line. Then the planners compared highway ROW land to see where the buffer and suitable land intersect. ▸



Map: NOAA National Centers for Environmental Information (NCEI), Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

The next step was to determine where the solar arrays could not be placed. Considerations included federal lands, protected lands, and urban areas, as well as any spots that were less than 500 feet from pipelines and less than 20 feet from railroad tracks. GIS is the perfect tool to combine layers of data and project constraints on a map where the situation can be visualized and analyzed. In Iowa, this level of location intelligence supported decision-making.

The result was 38,000 acres suitable for solar array installation, with the potential to generate five million megawatt-hours per year—that's $400 million worth of electricity.

The careful examination of layers of information is a location intelligence workflow that any organization can use to find suitable sites for assets. But considerations don't stop there. It is important to know which spots, among the possibilities, are most cost-effective and have the greatest return on investment. Those considerations can be nearly limitless—the available nearby workforce, material sources and costs, the most favorable regulatory environment, jurisdictions that offer rebates and incentives, and more. Each of these inputs has some level of location advantage and can be analyzed with GIS.

The Iowa analysis went deeper still. The next step was to use solar radiation models, including maps of elevation and vegetation, to measure solar array potential. This information revealed which sites among Iowa's ROW land should receive highest priority for solar array development.

Next, Iowa's traffic engineers needed to understand what the arrays would look like from the ground. For that, they used GIS to generate a 3D digital twin of each possible site. Relevant data could then be entered into the model to ask questions such as these: How would an array affect the view from a scenic lookout? How might glare affect a nearby subdivision?

"Transportation engineers know about asphalt, concrete, bridges, and signage," said Allie Kelly, The Ray's executive director. "When we start talking about solar panels, this is infrastructure that isn't native to them. The digital twin normalizes it."

A location-intelligent digital twin made the effort relatable for the state's engineers. On a broader scale, the use of a digital twin also allows various stakeholders to consider such issues as aesthetics, equity, and environmental justice. The Ray, for instance, can advocate for considering ROW lands that can also aid pollinators like birds and butterflies, thereby finding even more potential value in the projects.

The digital twin adds an element of human intelligence—the kinds of consideration any organization would need to make good decisions regarding possible sites—to the broader concept of location intelligence. As Kelly put it, "It lets us go from what we could do, to what we should do." ■

LOCATION INTELLIGENCE AND SUSTAINABLE AGRICULTURE

John Deere

By 2030, the global population will reach 8.6 billion. Feeding so many people is a top priority for policy makers and the farmers John Deere supports. The United Nations has established sustainable development goals including eradicating hunger, alleviating food insecurity, and establishing sustainable agricultural practices by 2030.

John Deere plays an important role in supporting the farmers who will achieve these goals. Guiding farmers to improve yields has been a hallmark of the company since it was founded as a tool manufacturer in 1837.

Though its mission remains the same, John Deere now looks and acts more like a technology company than an equipment company. At John Deere Labs, data scientists pursue research around the subject of precision agriculture and site-specific farm management. This work gives farmers the location intelligence they need to increase crop yields by varying resource allocation within a field. John Deere's innovation in this area has elevated field monitoring and location intelligence by applying the branch of artificial intelligence known as machine learning.

Dr. Angela Bowman works to help John Deere advance environmental sustainability from the local level to the very top of the company.

"Computer vision is helping growers see beyond our human capacity—what is happening at those critical junctures between plant and soil, plant and machine, and plant and weather—to help growers make important, in-the-moment decisions," explains Bowman.

Farmers face a number of unpredictable challenges each growing season as weather patterns, climate change, pests, and economic conditions all affect output and profitability. In the face of so much uncertainty, John Deere is empowering farmers with location intelligence to make real-time, analytics-fueled decisions about each of their crops and fields. ▸

One technology John Deere pioneered uses GIS, equipment sensors, and machine learning to allow farmers to spray herbicides directly on individual weeds, reducing chemical use by about 95 percent. In a billion-dollar industry, with so many factors in play, enabling farmers to manage their fields at the micro level adds up to significant environmental impact as well as improved profit margins.

John Deere has been at the forefront of precision agriculture since the 1990s and continues to advance the digital agriculture industry today, thanks to advances in sensor technology. "The data collected from the sensors also helps farmers to build maps of seed populations as well as specific field conditions and yield, informing not only decisions this year but for future years as well," says Bowman.

Technology inside John Deere's row planting machinery ensures that seeds are placed optimally to have the best chance of producing healthy plants and to grow crops equally across a zone or field. Using that same technology, farmers can see exactly where seeds are planted in their fields and apply that insight to more effective decision-making all season long.

Farmers are taking further advantage of their smarter, more agile machines by using John Deere satellite imagery to monitor a number of environmental factors in their fields, including weather patterns, pest impacts, and water table levels. By combining real-time conditions on the ground with historical data about the region on a map, farmers are able to make ecologically smart land-use decisions.

For example, John Deere was recently able to help a farmer make a critical decision about where to install artificial tile drainage in a valley that has historically flooded. The John Deere team used satellite imagery and underlying geographic data to pinpoint exactly where to place the tiles.

In another example, John Deere is helping farmers protect plants once they're in the ground. Although fields are typically only planted and harvested once each year, they are cared for many times during the season. John Deere developed location-based technology to inform farmers exactly where machines are in the field, within centimeters of accuracy. This guides the machines down the right path and ensures that they don't run over any fragile plants. John Deere is one of only five companies that has its own global satellite correction network to enable such precision.

John Deere leadership is expecting location intelligence to play an increasingly important role in the agricultural industry. According to Bowman, "The focus of the agricultural industry over the next five years will be on how to design and deliver automated machines that are smarter and more efficient and that respond to every square foot of farmable land, delivering dramatic improvements in profitability and environmental sustainability for a changing world." ■

LOCATION INTELLIGENCE TO KEEP PEOPLE MOVING

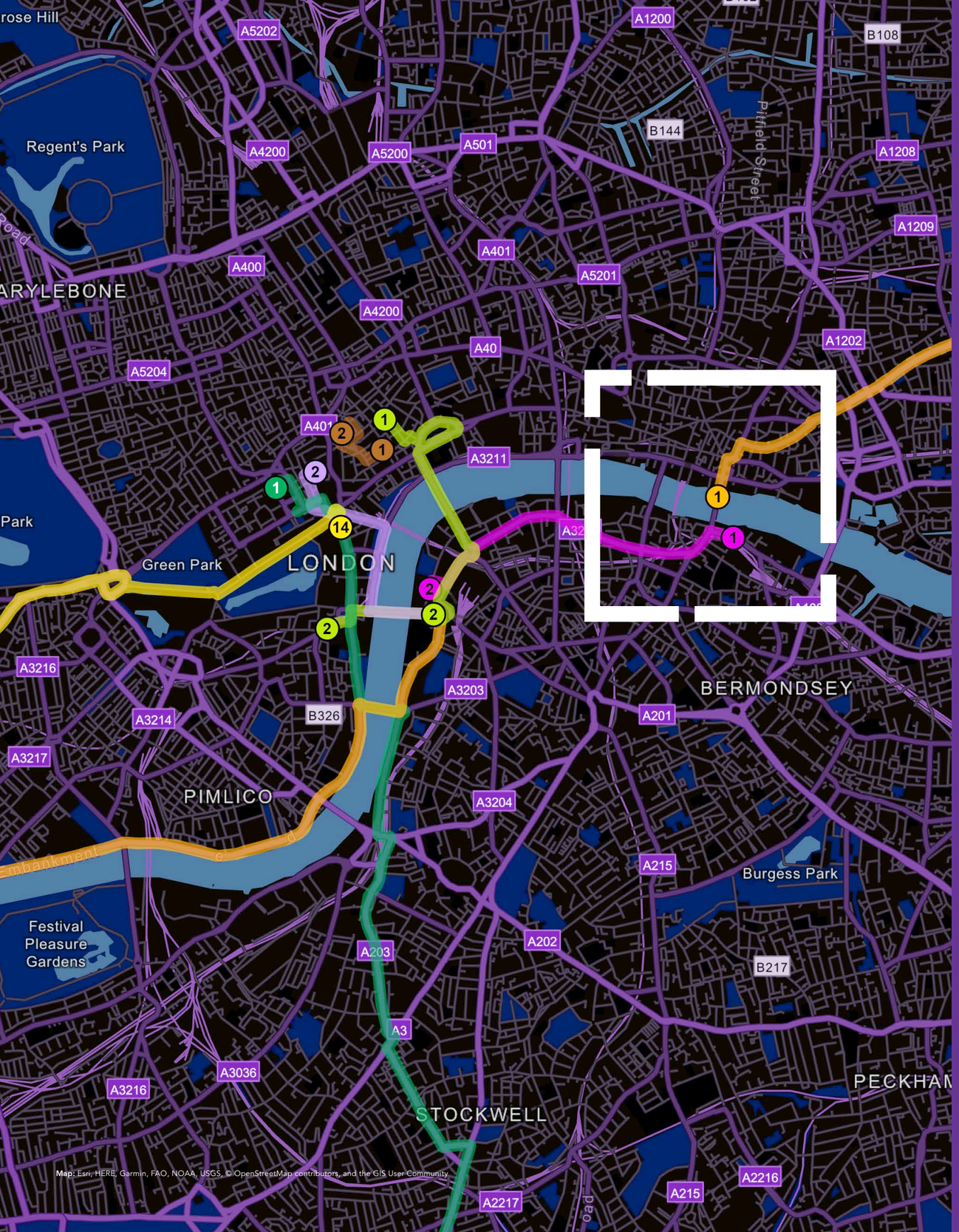
Transport for London

Every day, three million people ride public transportation in London, the United Kingdom's largest city. The number of passengers equals the total population of the next four largest British cities. Planners at Transport for London (TfL), the city's transit authority, move these people by using a geographic approach that balances demand by searching for ridership patterns. TfL uses location intelligence every day for every journey and gathers ridership information to inform maintenance and expansion of the system.

The evolution began during the 2012 Olympic Games, when TfL employed location intelligence to deal with a 20 percent increase in daily ridership. By adding sensors to trains and buses and monitoring security cameras, TfL created situational awareness that allowed it to assess real-time changes in traffic patterns. TfL credited this awareness with mitigating bottlenecks and breakdowns to keep the city moving when ridership reached record levels.

A GIS-based traffic management tool called the Games Playbook helped planners visualize the increase in traffic and create contingency plans for different scenarios. The plan and the real-time view of traffic allowed TfL to send advisories to travelers. "That's the biggest legacy in terms of behavioral change," Michelle Dix, TfL's planning director at the time, told the BBC. "We proved that by giving people alternatives so they can make informed choices, you can manage these big events."

After the Olympics, TfL began a strategy that combined messaging and a geographic approach, sharing location intelligence with key stakeholders and across the organization. ▸



Adapting Strategy to the Global Pandemic

In 2014, TfL kicked off a 10-year plan, known as the Surface Playbook, to connect its many directorates managing London's aboveground transportation, including buses, trams, light-rail, commuter trains, passenger ferries, the Dial-a-Ride transport service for people with disabilities, London's congestion pricing program, and the taxi licensing office.

GIS allowed these diverse stakeholders—already united in the goal of keeping Greater London's interlocking transit systems running smoothly—to see current traffic conditions through a single source of truth.

The Surface Playbook effort proved vital when the pandemic hit. Using the maps the transit authority had already created, TfL applied the communications and public affairs skills honed during the Olympics to encourage safe active modes of travel.

The program was designed "to support the members of the public to have more confidence to walk and cycle," explained Jaymie Croucher, TfL's lead for GIS. "It's focused on supporting sustainable modes of travel and increasing the ability to enact social distancing in transit whilst limiting the impact of other modes."

From big-picture perspectives to street-by-street analysis, the program had an important equity component, using maps to make sure no London community remained isolated during the lockdowns. TfL's GIS team identified at-risk and high-demand areas of pavement, based on five major factors: use by cyclists and pedestrians; essential services; population density; low-income neighborhoods, which usually have above-average amounts of foot traffic; and public transportation hubs.

Maps revealed which streets were likely to be the most crowded and where more space was needed for safe and physically distanced activity. Risk assessments could even be layered over maps of walkway widths to identify capacity while keeping everyone spread apart. Measures included widening walkways, creating temporary bike lanes, and restricting the use of cars on some streets. ▸

Continuing the Process as the Pandemic Fades

As the pandemic wanes, the Surface Playbook has been instrumental in crafting a cautious return to normalcy. TfL officials are using GIS to determine which pandemic measures and active transportation routes should be considered permanent.

"Before we can decide whether a feature becomes permanent or not, we need to understand what the impact is," Croucher said. "If you close a street, for example, that is going to cause traffic to develop elsewhere."

On-site surveys have been a key component of the monitoring process. Surveyors across the Greater London area capture data about use, safety, and needed improvements. Survey feedback populates a live, online GIS dashboard, providing real-time visibility and informing next steps for city management.

Shareable reporting tools have also supported TfL's expansion into new parts of the city. With many transportation projects being carried out by the boroughs within London, a GIS database centralizes information and makes essential data widely available.

"Compiling it all within a single portal, we've allowed everyone to have transparency over the safety of each scheme and compliance of users," Croucher said. The portal delivers situational awareness for TfL and city leadership to see how each plan performs and interacts.

Changing a city's transportation habits ultimately requires a strategic rebalancing of the way residents use city streets. Recreation, public transit, transportation of people and goods—each claims a space. Giving more space to one will necessarily take space from another. Maps provide a powerful visual understanding of the space available and a strong platform to plan, prioritize, and improve its uses.

"The benefits of the way we collect and disseminate this information are reaped well beyond TfL to provide clarity to both external partners and, ultimately, the public," Croucher said. "Understanding the spatial relationships that elements have provides a clear picture for decision-makers that you won't necessarily see by looking through more traditional means such as a database or a spreadsheet." ■

A DYNAMIC DIGITAL TWIN ENABLES TRANSFORMATION

San Francisco International Airport

San Francisco International Airport (SFO) is the world's fourth-largest international gateway airport and the leading airport connection to the Asia-Pacific region. SFO's management originally adopted GIS to comply with the Federal Aviation Administration's (FAA) NextGen program, an 18-year modernization initiative launched in 2007. One NextGen requirement is that airports provide data in a GIS format to support satellite-based approach guidance systems.

SFO became the first airport in the western Pacific region to receive a grant from the FAA to achieve compliance using GIS. While the FAA focuses on GIS for detailed awareness of the horizontal infrastructure—runways, taxiways, pavements—SFO saw an additional opportunity. Staff are applying GIS to support facility management operations such as construction, maintenance, emergency response, and space planning.

SFO embarked on a multibillion-dollar capital improvement program that includes construction of a new hotel, modernization of two terminal buildings, and extension of the AirTrain system. Before the work could begin, the airport needed to centralize data for efficiency and safety. Managers needed to establish data standards. And it was imperative that information sharing be effective and streamlined across the teams involved in the capital improvement project.

The airport's management decided to leverage GIS, which can integrate with building information modeling (BIM), and create a dynamic digital twin that includes indoor and outdoor data. ▸

Map: Image courtesy of SFO

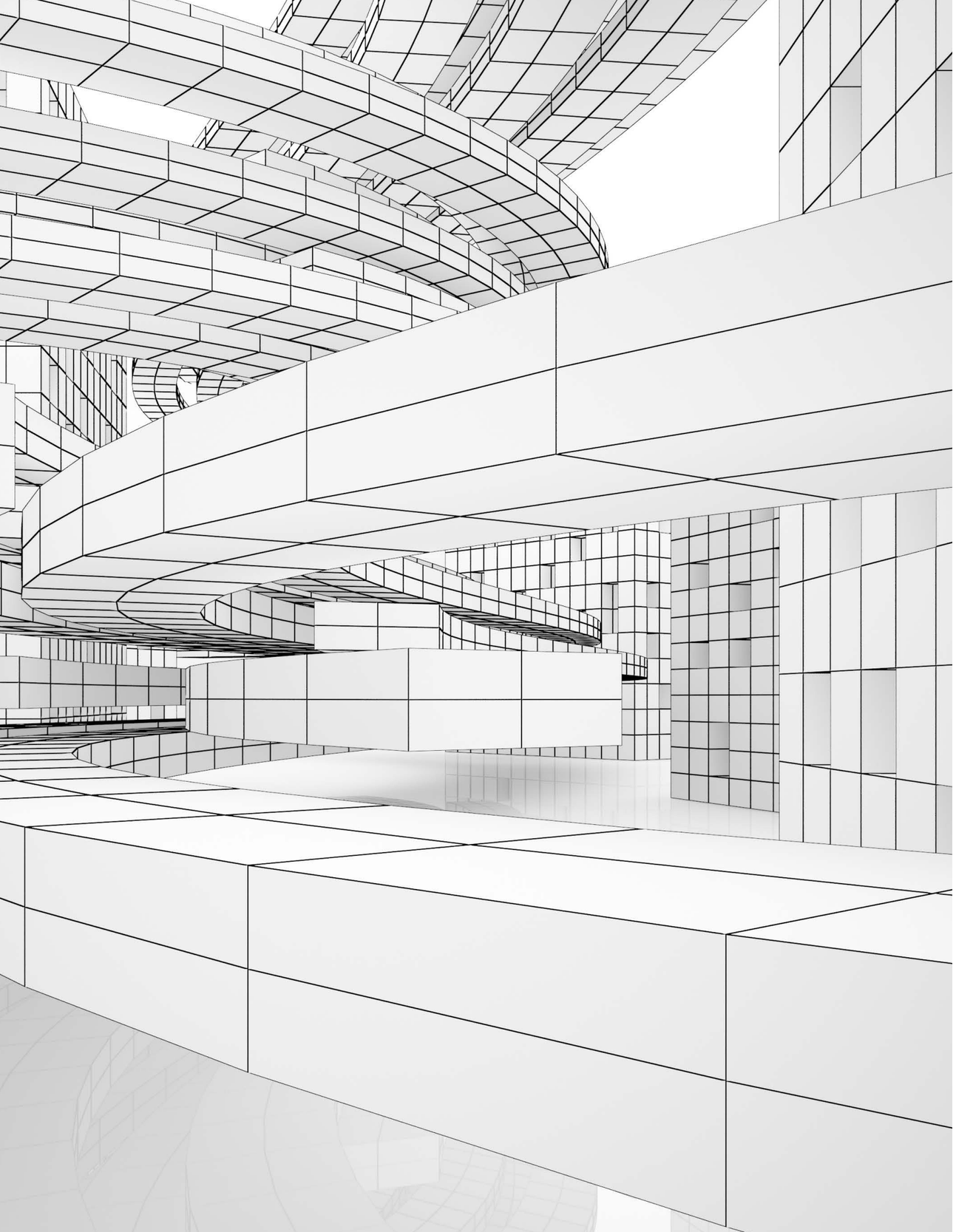
The Dynamism of Digital Twins

A digital twin describes any virtual system that mirrors a real-world counterpart. Three-dimensional digital twins can now emulate enormously complex and dynamic systems. They allow an observer to gather maximum contextual information about the present state of the system, compare it with records of the past, and even gather realistic assessments of how changes will affect it in the future. A GIS-based digital twin is really 4D, capable of integrating the variable of time.

"We use GIS as the window of entry to all our infrastructure information," said Josephine Pofsky, SFO's director of infrastructure information management. "It can be overwhelming, because we are changing the industry and organization's mindset by leveraging the power of virtual design and construction through integration of BIM and GIS. The capital program provided the opportunity."

SFO's digital twin is notable for its size and scope. Around the world, pockets of planners, managers, and architects have begun to push the limits of digital twin technology, creating twins of entire cities and even small nations. SFO's digital twin is similar to a city-scale system. For instance, SFO covers a wider area than San Bruno, a city that borders the airport, and it employs 46,000 people—about as many people as there are living in San Bruno. Also, the number of rooms inside SFO (15,000) compares with the number of housing units in San Bruno. This further illustrates the scale and amount of work that goes into creating a digital twin of an airport as it's equal in size and complexity to a small city.

SFO prefers the term *dynamic twin* to reflect its continuous alignment with the ever-changing real-world environment. The goal is not to preserve each as-built model captured right after construction but to transition it into an as-managed model where it can continue to serve stakeholders. "It's up to us as the owner to keep it alive throughout the life of the infrastructure," Pofsky added. ▸



The Twin Lives On

With SFO's dynamic twin established, it can be adapted to purposes that extend far beyond individual construction projects.

For example, it helps the airport's management team keep track of leased commercial space. Team members use the twin to find the best location for a new kiosk or a specific retailer, valuing GIS for its ability to filter and query information to get answers and recommendations.

Similar to cities, airports have a variety of service-oriented departments, public safety offices, and 911 dispatch systems. SFO's 911 network was recently updated and integrated with GIS to provide accurate and up-to-date emergency service information.

"With that integration into the 911 system, our first responders, including our communication dispatchers, are looking at the most up-to-date floor plan information," Pofsky said. "They can virtually walk through the space in 3D."

One of the upcoming initiatives is to enhance traveler experience by developing indoor navigation capabilities that utilize SFO's dynamic twin.

"Airports can be stressful in the eyes of many travelers," Pofsky said. "It's about delivering advanced knowledge to the user and the passenger so that they feel more in control of the experience going through the airport." ■

EMBRACING THE SHIFT IN TRANSPORTATION

Colorado Department of Transportation

Mobility is the catchall term to describe ways of moving people and goods between points. New categories of vehicles, business models, sensors, networked cars, artificial intelligence (AI) algorithms, and fuel sources make the future of mobility difficult to predict. Departments of transportation work to stay on top of the changes. They must behave somewhat like autonomous vehicles, quickly perceiving, thinking, and acting on real-time data to keep innovating and progressing.

"Location data is central to our success and that of autonomous vehicles," said Barbara Cohn, chief data officer with the Colorado Department of Transportation (CDOT), "because knowing where you are and what is around you is absolutely critical."

Transportation departments have a long history of using networked cameras and conditions. The next wave of this technology involves using information from sensors embedded in bridges and roadways to inform maintenance needs. Now, there is an ever-increasing volume of input from motorists and transportation crews interacting with applications. Departments have begun to aggregate input from connected vehicle-to-vehicle wireless communication.

Location provides the common data element that links activity on roads, rails, and runways with the activities that CDOT engineers and work crews perform to maintain and construct mobility networks.

"Every asset we manage, from roads to bridges, has not only a specific location but also environmental conditions that affect performance," said Joshua Laipply, chief engineer, CDOT. "Detailed mapping to capture many attributes is critical to maintaining, operating, and designing our roads." ▸

Apps to Integrate Operations

Cohn and her team are working to create a strong and sustainable foundation to support the data needs of the transportation system of the future. CDOT is expanding the use of data and GIS tools across the agency and has recently embarked on a transformation to migrate data from siloed systems to purpose-built applications.

For example, the traffic operations dashboard ingests data feeds from the Waze navigation app; data from roadway traffic sensors; National Oceanic and Atmospheric Administration weather data; and traveler alerts and road condition information. In one interface, the dashboard provides quick visibility into transit status and conditions.

Another app, the Statewide Transportation Improvement Program (STIP) viewer, extracts information from a variety of systems to show a four-year view of projects and the status of each.

Other apps are much more specific. An avalanche mitigation dashboard displays the location of historic avalanches and what's currently happening with weather and snow conditions. A nighttime inspection mobile app is being used by road crews to record the effectiveness of road reflectors and the condition of paint in order to flag areas that need maintenance.

"Linking location with the power of visualization makes visible the invisible, providing invaluable input for the discovery of trends, patterns, and insights," Cohn said. ▸

Quality and Value

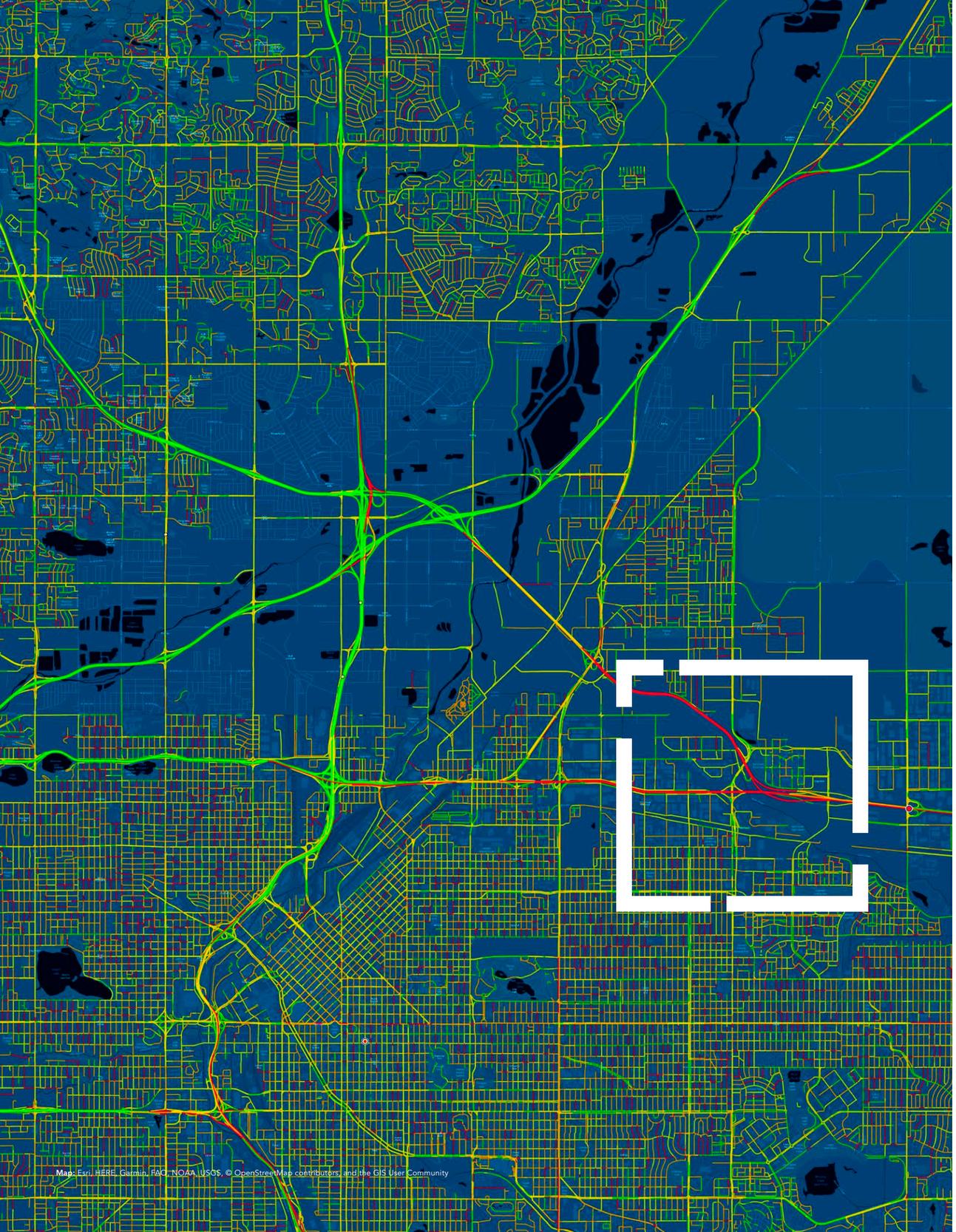
A wide variety of CDOT applications use disparate data, which puts a spotlight on the value of high-quality data.

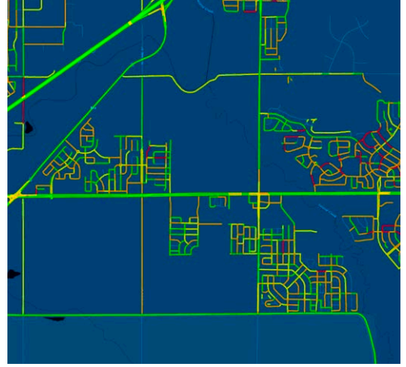
"People are asking questions about the data, and there's a thirst for more information," Cohn said. "With each app, we move the organization closer to a data-driven culture."

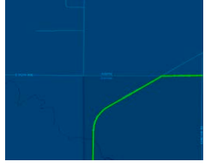
Exposure to data-driven maps and dashboards has also inspired enthusiasm for self-service business intelligence tools.

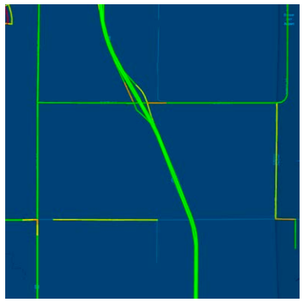
"We're democratizing data," Cohn said. "We've embarked on a journey to provide data as a service, data on demand from authoritative sources, capabilities for advanced analytics, predictive modeling, and more."

CDOT recognizes data as one of its most strategic assets. But having data is not the same as knowing what to do with it. Location-based apps help turn raw data into actionable knowledge. ▸









Growing Demands

Rapid population growth in Colorado has brought increased traffic and congestion. To combat the growing pains, CDOT increased its real-time data streams and adopted new methods of analysis and data modeling while also looking at redesigning roadways.

"We look across all modes of transportation for answers," Laipply said. "The solutions lie with pedestrians, cyclists, transit, and rail as well as roadways. We're looking at autonomous cars and the hyperloop. We're really looking at it from a holistic view of smart mobility."

CDOT partnered with Panasonic's sensing team to pilot the use of vehicle-to-everything (V2X) communication technologies in critical mountain corridors. The resultant system picks up sensor feeds such as signals from brakes or windshield wipers to alert other vehicles about rapidly changing driving conditions.

"V2X will give roadway operators the ultimate situational awareness with highly accurate geolocated travel information and localized weather data, resulting in faster emergency response times, improved incident management, more intelligent and coordinated traffic signals, improved information about parking availability, and enhanced maintenance decision support," Laipply said. "We're headed toward the internet of roads that will be able to communicate." ■

THE BUSINESS VALUE OF SUSTAINABILITY

Nespresso

"WE ARE WORKING QUITE EXTENSIVELY TO UNDERSTAND THE IMPACT OF CLIMATE CHANGE AND EXTREME WEATHER AROUND FARMS AND ALSO THE IMPACT OF FARMS ON THE SURROUNDING ENVIRONMENT."

—YANN DE PIETRO, OPERATIONS AND SUSTAINABILITY TECHNOLOGY MANAGER FOR COFFEE AT NESPRESSO

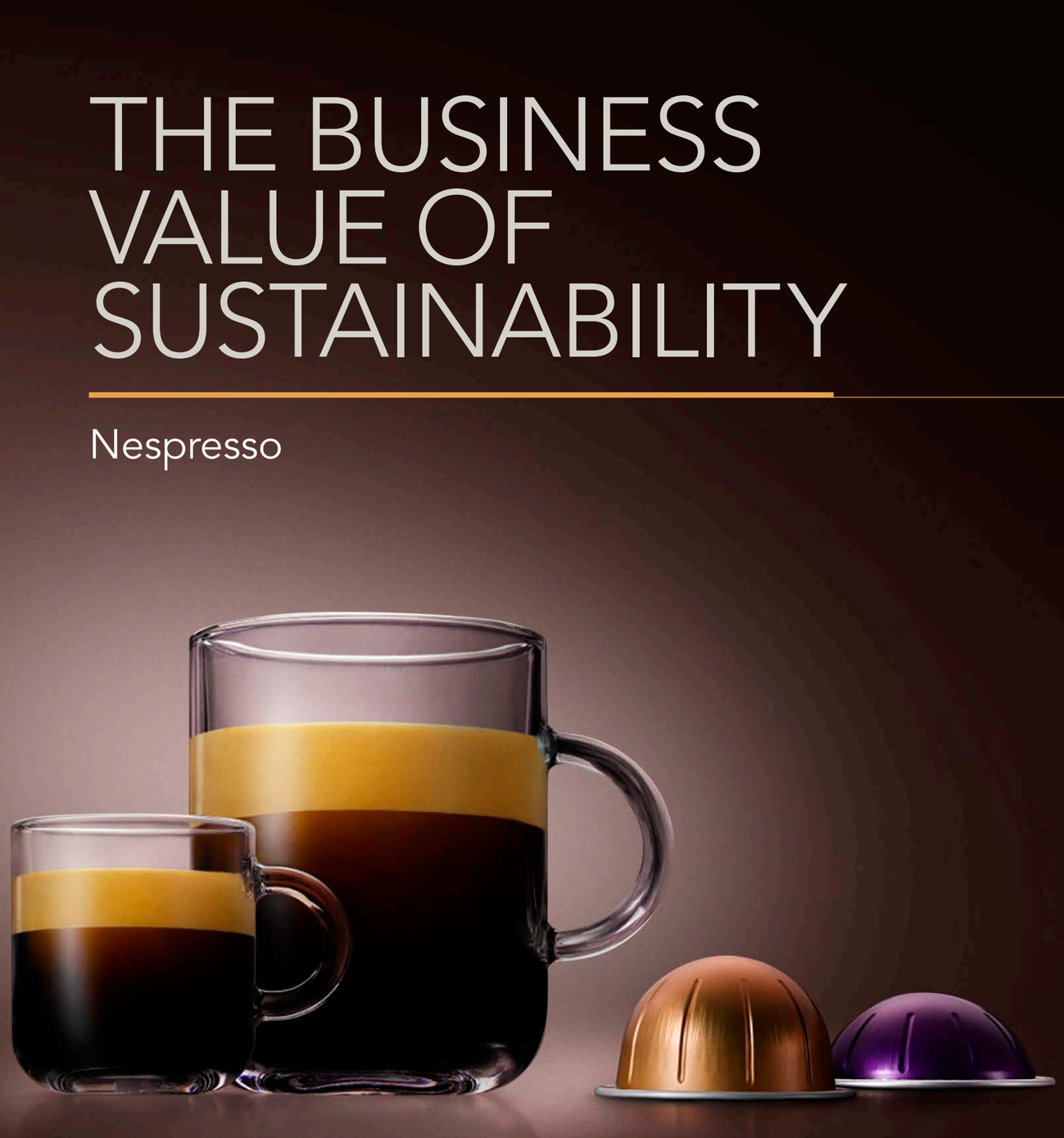


Photo courtesy of Nespresso.

Innovative companies are adopting big data analytics and location intelligence to drive smart, sustainable practices for long-term growth and competitive advantage. One such company is Nespresso.

An autonomously managed subsidiary of Nestlé Group, Nespresso is known globally for its premium single-serving coffees. Key to Nespresso's success and customer loyalty is the company's emphasis on—and investment in—the consistency of its coffee's flavor.

However, coffee is a delicate crop, frequently grown in developing countries and is highly dependent on healthy ecosystems. This leaves coffee—and Nespresso—susceptible to the increasingly volatile effects of sociocultural events and climate change. For Nespresso, acting today to avoid the perils of tomorrow is not just good stewardship; it's sustainable business.

"Sustainability is really at the core of our business. It is imperative to our long-term business success," said Yann De Pietro, operations and sustainability technology manager for coffee at Nespresso. "There have been studies saying that by 2050, arabica coffee may not be available anymore in some countries if we don't do anything now."

The company is working to combat that decline and maintain Nespresso's competitive advantage long into the future. ▸

Photo courtesy of Nespresso.

Controlling Challenges through Sustainability

Nespresso works with more than 100,000 farmers in 13 countries, up from 300 farmers 15 years ago. In 2003, the company launched its responsible coffee sourcing program, the Nespresso AAA Sustainable Quality Program, in partnership with the Rainforest Alliance. The program is founded on two convictions: that high-quality coffee and the sustainability of farming communities are interconnected, and that only by building trusting, long-standing relationships with coffee producers can Nespresso hope to make a positive difference.

The company supports the implementation of sustainable agricultural practices by investing in technical assistance, paying premiums directly to coffee farmers, and cofinancing infrastructure improvements.

As part of that effort, the company has invested in a network of over 450 agronomists—specialists who provide coffee growers with on-site technical assistance and trainings on practices such as pruning, crop renovation, fair treatment of workers, water usage, and biodiversity conservation.

Through the AAA program, Nespresso invests approximately US$35 million per year in technical assistance and premiums paid to farmers for their quality coffee. The educational program is free to farmers and doesn't require them to sell to Nespresso, De Pietro explains. But the benefits to each side help create long-lasting relationships and loyalty.

Nespresso has a publicly stated goal of sourcing 100 percent of its "permanent range" coffee—the brand's most prominent line of coffee capsules—from AAA farmers by the year 2020. In 2017, the company bought approximately 90 percent of its beans from those farmers.

The AAA Sustainable Quality Program falls under Nespresso's broader strategic framework, The Positive Cup, which focuses on four areas: coffee, aluminum (used for making coffee capsules), climate change, and engagement. In addition to its goal of sourcing all coffee from AAA growers by 2020, Nespresso has committed to milestones such as sourcing 100 percent of its aluminum from responsible, Aluminum Stewardship Initiative (ASI)-certified sources, which offers convenient solutions for recycling, reducing the carbon footprint of each cup, and reaching carbon neutrality for its operations. ▸

Photo courtesy of Nespresso.

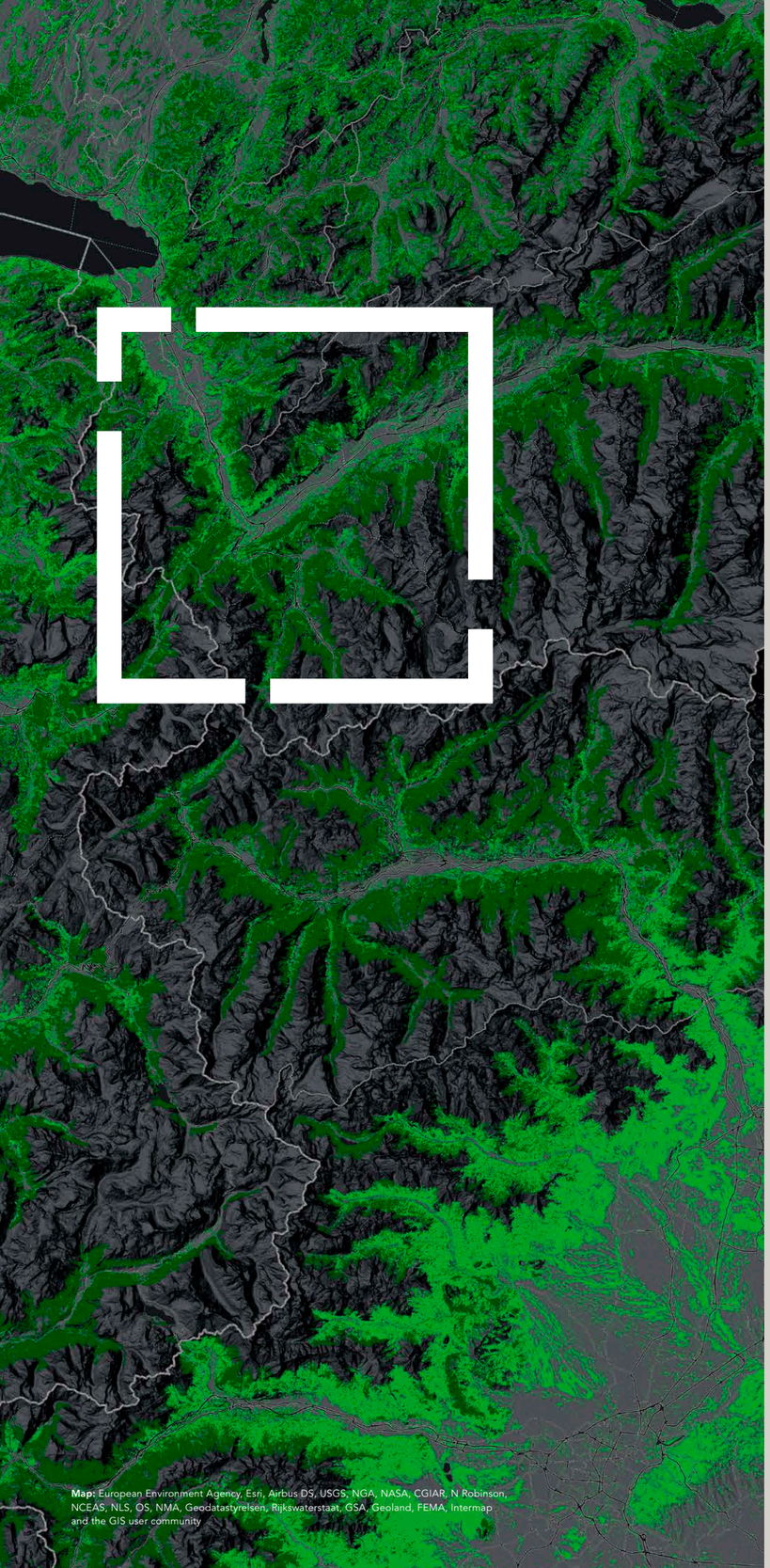
Progress through Digital Transformation

While its sustainability program has been in effect for years, Nespresso has seen recent rapid results due to advances in digital technology.

"Digital transformation is a key change for sustainability at Nespresso," De Pietro said. "[We] want to provide maximum impact. So we need the tools to help us maximize our efforts."

On the balance sheet, the results look promising. When Nestlé announced its first-quarter 2021 results, it singled out Nespresso's double-digit growth. The parent company's growth was led by coffee, and Nespresso has continued to expand production and distribution. It added 10 new lines for coffee capsule production. In March 2021, Nespresso unveiled a new flagship store concept in Vienna, Austria, expanding the in-person customer experience to enable greater customization and service.

At the center of Nespresso's sustainability and digital transformation is location intelligence. The company has built a robust monitoring and evaluation system using advanced technology that records, maps, and analyzes data about farms, farmers, and coffee crops. Nespresso can assess local feedback, see the status of each farm, and gain insight into AAA's impact. Data analytics powered by GIS also reveal insights into the way farmers deliver coffee beans to central mills to be harvested—a key factor in supply chain productivity and efficiency. ▸



Map: European Environment Agency, Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

The Advantage of Bringing Intelligence to Location Data

One of De Pietro's goals is to help farmers get their crop to market more efficiently. Recent analysis in Colombia exemplified how location intelligence can create business advantage for the company and its partners. The data showed that farmers brought their crops to certain Colombian mills—many of them close to their farms—less frequently than projected. De Pietro used GIS to dig deeper into the data so that he could understand these behavioral patterns. What he discovered was a reminder of topography's effect on time to market.

With basic maps, he said, his team could work out the distance between farms and mills. But only with sophisticated location intelligence could staff understand the true travel distances to each central mill. Applying an analysis that was similar to one on the frequency of agronomists' visits to Nespresso's AAA farms, De Pietro and the team found a familiar pattern. The analyses uncovered areas where the terrain between the mills and certain farms required long rides or walks through the mountains, making frequent visits impractical.

In both cases, location intelligence pointed the way to better business and sustainability practices. If the mills were more centrally located, farmers could get coffee to market more quickly. And when the agronomists can reach farms faster, they hasten the day when 100 percent of Nespresso's coffee is sourced from sustainable farmers.

Just like retailers and logistics companies that use location intelligence technology to plot the most efficient drive times for customers or delivery personnel, Nespresso embraces the realization that the distance to a location is less important than the amount of time it takes a customer or farmer to get there. Today Nespresso is using location intelligence from GIS to build a comprehensive understanding of climate and geography around its farms. "We are working quite extensively to understand the impact of climate change and extreme weather around farms and also the impact of farms to the surrounding environment," De Pietro said.

The use of location intelligence to shed light on the granular details of day-to-day coffee farming sets Nespresso apart. By examining locations for farmers, the company frees up precious time and increases productivity. This impacts not only farming but also time for education and strategic planning—the very activities Nespresso hopes will sustain its coffee crops far into the future.

Nespresso's core product and the heart of its brand—coffee—is at risk from climate changes in coming years. The company is approaching these challenges proactively, taking steps to not only mitigate risk but also use location intelligence to create strategic differentiators.

Treating sustainability as both a guiding principle and an opportunity to gain competitive value may be the way forward for other innovators in the business community. ■

Map: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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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