INTEGRATING KNOWLEDGE WITH GEOSPATIAL DIGITAL TWINS

Many Types of Digital Twins
Provide Context and Connections
to Increase Understanding

esri

"An open digital twin—incorporating measurement, models, and analytics—has an opportunity to codify an open science platform. It wouldn't be constrained to just local geographies or the natural world, but include all of social science and how things are related and interrelated."

–Jack Dangermond,
Esri Founder and President

WHAT'S INSIDE

EXECUTIVE SUMMARY

A digital twin describes any virtual system that mirrors the objects, movements, and relationships of its real-life counterpart. A digital twin shows the state of the system as it is now, as it was in the past, and as it is likely to be in the future.

Digital twins have entered the mainstream. Companies and organizations across nearly every industry are discovering digital twins' value. Although applications vary, they have common objectives. Digital twins offer clarity and a framework for making crucial decisions.

Before making real-world decisions, leaders test scenarios using the digital twin. It provides a place to try ideas before spending time and money or disrupting projects. It delivers the information that any leader requires to make decisions and act. It also provides the means to monitor operations. By observing the current state or changes over time, smart strategies emerge.

GEOSPATIAL DIGITAL TWINS

A geospatial digital twin is one built on a foundation of geographic information system (GIS) technology. As digital twin technology has advanced, geospatial digital twins have emerged as being the most comprehensive, versatile, and useful.

A geospatial digital twin aggregates the data that is found all around us. The data leaders need to make informed choices. Sensor networks and Internet of Things (IoT) devices produce a constant stream of information. Often, the only attribute these various forms of data share is location. A geospatial digital twin depicts this commonality, revealing how the various types of data exist and interact in relation to one another. Together, this data provides an intelligence edge, adding context about critical places.

It does this by displaying data using the common visual language of maps. By emphasizing the *where* of data, decision-makers gain the perspective to observe the *why* and *how*.

THE INTEGRATIVE POWER OF MAPS

United on the Common Canvas of the Map, Connections Emerge and Relationships Are Clarified

A digital twin helps architects and engineers test scenarios during the planning stage of a building project. Based on traffic patterns and demographic projections, how would current plans impact the area? As construction proceeds, that same digital twin is updated to display progress toward completion.

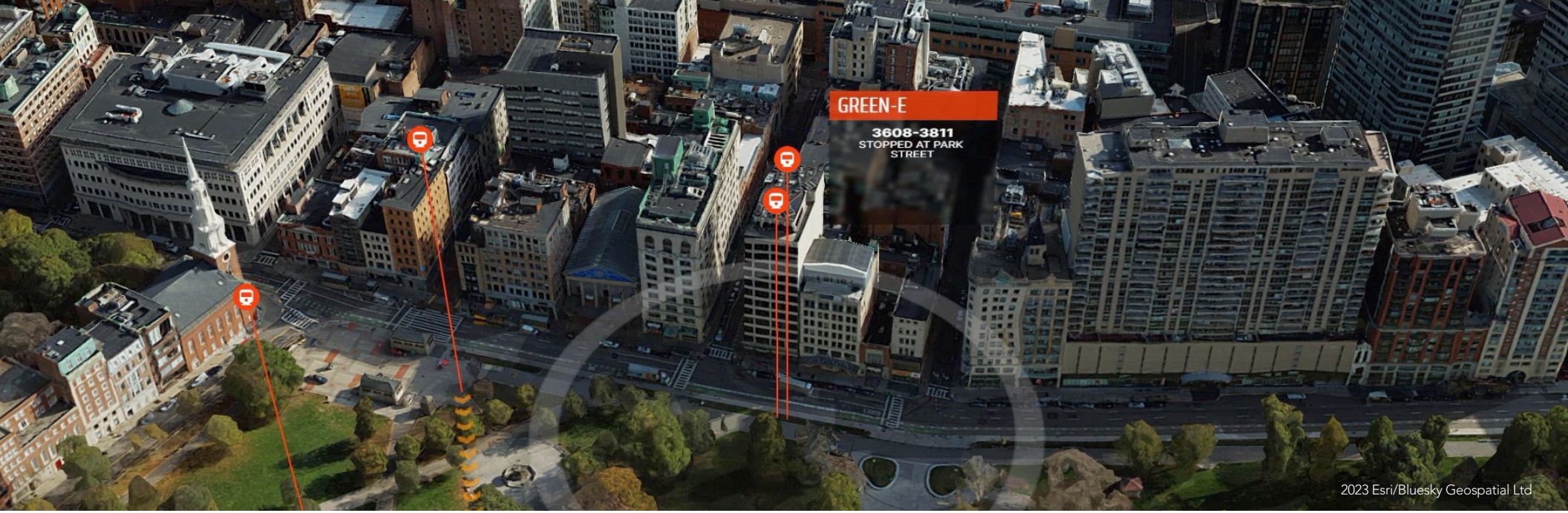
A supply chain manager sees the company's complex web of manufacturing and distribution tasks. The many steps necessary—various factories of different suppliers making components that are assembled elsewhere, the logistics of moving the finished products around the world—come into focus.

A hospital uses sensor data to understand the locations of assets and patients. This tells staff if they are facing a shortage of beds or if more personnel need to be moved to the emergency room. Big-box retailers do something similar, noting where customers congregate in relation to specific offerings.

Federal programs allocate funds to address underinvestment in disadvantaged communities. Cities and businesses use demographic data to understand racial equity and make more equitable decisions about the delivery of services.

The ability to test future conditions will become increasingly important as climate change creates more volatility. Geospatial digital twins are now commonly used when planning infrastructure projects. They allow engineers to test the project against various future climate scenarios, with an eye on weather extremes.

Carbon capture and storage initiatives require a careful accounting to contextualize activities that produce emissions or can sequester them. A geographic approach puts the focus on efficiency—and profitability—to support a greener future.



BEYOND 3D MODELING

The Many Applications of Location Intelligence

Digital twins are sometimes described as 3D models, but that description glosses over the value of digital twins. A 3D model may be meticulously accurate, but it is a snapshot, a frozen moment. A digital twin is dynamic, modeling change over time.

Nearly every decision a leader makes will involve change over time: the present situation, how it has changed, and how it is likely to evolve. Any digital twin, by design, includes this temporal element. This trait is what distinguishes even the simplest digital twin from a 3D model.

Digital twins evolve. This is what makes them such powerful analytic tools. It is what makes them seem real.

Geospatial digital twins have now reached a level of realism that justifies the term *reality capture*. The geospatial digital twin aggregates high-resolution data with models from building information modeling (BIM) software and GIS data. Drone and satellite footage can help extend digital twins over entire cities or nations. Gaming engines turn these digital twins into truly immersive environments within virtual reality headsets.

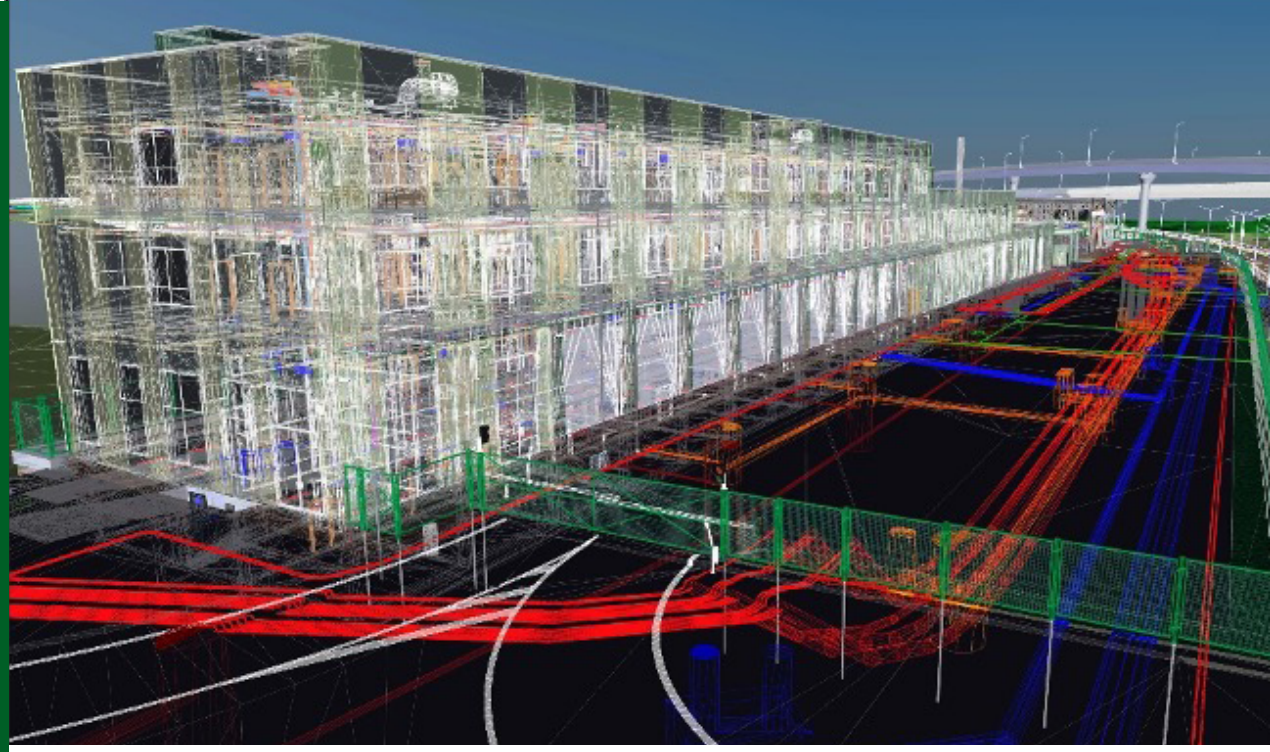
The decisions you need to make for your business demand this ultimate command of the physical environment. Geospatial digital twins are not meant to imitate the world. They are tools to help understand it.

DESIGN AND CONSTRUCTION DIGITAL TWIN

Constructing Better Buildings and Built Environments

Digital twins are increasingly essential tools for the construction industry. In the planning stages of a building project, they allow architects and engineers to design with a realistic model. With projects that have multiple contractors and subcontractors, digital twins provide a way for everyone to contribute their plans to create a cohesive whole. The many stakeholders see a project come together, in a way that provides maximum contextual awareness.

The same digital twin becomes invaluable for crews in the field during the construction process. It lets them see exactly what the project requires and how it fits into the larger environment. The model conveys designs alongside special instructions. And as construction proceeds, the digital twin mirrors the progress, showing exactly what has been built and what comes next. These visuals make the project's progress understandable for all stakeholders, in a way that written reports cannot.



With Many Large Projects Now Being Built Using GIS and BIM Technology, a Must-Have Approach Has Emerged

There are three things to do that simplify and advance the value of the ArcGIS® GeoBIM℠ technology-based process:

- Create a common data environment. Any project-related dataset, no matter what the format—GIS, BIM, volumetric, photogrammetry (a three-dimensional coordinate measuring technique that uses photographs)—should be in a central repository.
- Require all contractors to use the same standards in their 3D architectural models so that they can be combined into a single digital twin for the project.
- Make the model immersive. Using game engines and virtual reality headsets allows anyone sitting anywhere to be transported inside the place they are designing and set to build.

The value of a digital twin for construction projects extends beyond the visual. Architects and engineers face pressure to make their projects sustainable. As the world confronts a net-zero carbon emissions future, digital twins quantify exactly the amount and impact of carbon emissions involved in building a project, as well as what energy performance to expect when a project is completed. And when it is completed, the digital twin continues to provide a way to monitor projects and engage in operations and maintenance.

CASE STUDY

In Australia's Fastest-Growing City, a Digital Twin Guides Rail Expansion

Cross River Rail Delivery Authority

Situation

The team tasked with designing the first underground railway under the heart of Australia's fastest-growing city faced a delicate task. The project to tunnel several stories under the teeming center of the city had to come off without disruption. And constructing expansive subterranean stations would be a first in the country.

Challenge

Coordinating data and the work of contractors and subcontractors can be daunting. If they are using different types of software that don't interoperate, it creates chaotic jumble of information that adds complexity to an already complex undertaking.

Solution

The Cross River Rail team mandated a federated BIM model, collecting all the data in a design and construction digital twin.

Rather than consider the BIM models as inert objects floating in space, people involved in the project use it to visualize what's around them. In GIS they see how each structure fits into the infrastructure aboveground (such as paths, roads, and light poles), the infrastructure underground (the pipes and lines that connect utility services), and the natural world (landscaping, groundwater, and even wildlife and biodiversity considerations).

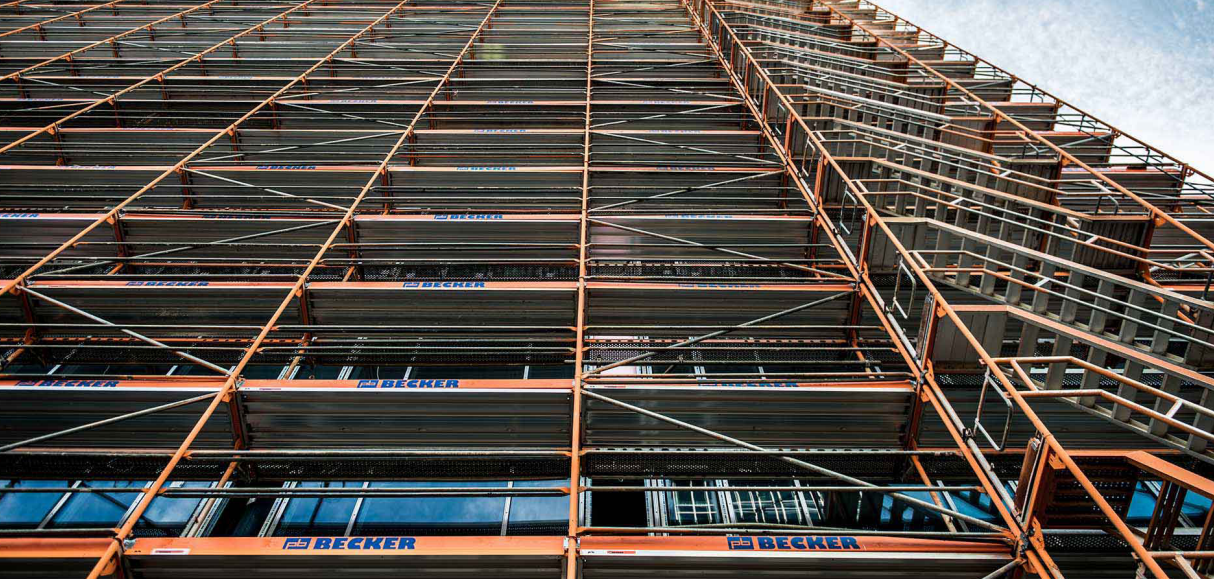
Result

With all the data being digital and in 3D, Brisbane planners are finding no end to its utility. A game engine transforms the digital twin into a virtual reality tool for walking through designs, planning complicated construction, and communicating progress. The digital twin is now being used to operate the system, adding to its value in design, construction, and project management.

☞ Read the story.

"We realized we've built a digital twin that will help run the railway, so there's almost a whole second chapter waiting to be written."

–Russell Vine,
Chief Innovation Officer,
Cross River Rail Delivery Authority



CASE STUDY

Buildings Aim for a Net-Zero Future

Ecoworks

Situation

The built environment accounts for nearly 40 percent of energy-related carbon emissions. Building operations cause the majority of emissions due to poor insulation, electricity generated by fossil fuels, and other factors. The rest comes from embodied carbon—emissions created during the manufacturing of building materials and in the construction process.

Challenge

Changing the process of constructing new buildings—so that the amount of embodied carbon decreases—will not have sufficient impact. An estimated two-thirds of the world's current indoor space will still be in use in 2040. But retrofitting existing structures to make them carbon-neutral is expensive and time-consuming.

Solution

Ecoworks, a Berlin-based startup, is pioneering a second-skin retrofitting process. First, 3D scans of a building's facade and interior are gathered with a handheld device. This becomes a digital twin that is sent to a factory where a highly automated process yields panels that fit over the building, with room for windows, pipes, and ventilation shafts. The process of installing the panels, along with a modular roof equipped with solar technology, requires just a few weeks.

Result

The digital twin serves another purpose as well. After construction, it provides the foundation of a GIS-based system for quantifying decarbonization efforts.

☞ Read the story.

Reality Capture from the Air, on the Ground, and from Models

Modern maps reflect the world around us. High-resolution imagery, BIM, and GIS make this possible. The resultant representation goes beyond mapping. The new term to use is *digital twin*.

ArcGIS® Reality creates realistic models for a site, a city, a state, or a whole country. It supports inputs of imagery from drones, planes, helicopters, or satellites. The sensors used include full-frame multicamera arrays, lidar, and single cameras. The software transforms the data into detailed representations that show places and situations as they are.

Terrestrial lidar adds realism to inform engineering decisions. The dense points from this technology offer details with centimeter-level accuracy. Within GIS, designers and engineers visualize and analyze the data to derive measurements and insights.

Esri and Autodesk have partnered to bring GIS and BIM together to add context to the life cycle of any project. GeoBIM creates digital representations of environments, assets, networks, and cities. Workflows support the planning, design, construction, operation, and maintenance of physical infrastructure.

A digital twin makes it easy to share and communicate important up-to-date details with everyone. This digital reality tool reduces risks, optimizes operations, improves business processes, and enhances decision-making.

PLANNING DIGITAL TWIN

Reenvisioning Urban Growth with a Focus on Sustainability

For the first time in history, more than half of the world's population lives in cities—and that segment is projected to rise to 70 percent when the world's population reaches 10 billion. Life on earth is increasingly synonymous with urban living.

This puts an enormous amount of pressure on today's urban planners. Cities cannot be built based on prior methods of growth and expansion. Planners must balance population pressures with sustainability. They must demonstrate climate resilience. They must design cities for walkability, where car dependence is minimal, public transit is plentiful, and a future of net-zero carbon emissions is possible. They must build equity into their plans so that city services are allocated equally and climate change impacts are not felt unequally.

One difficulty of achieving these objectives is that there is a limit to how much planners can treat cities as living laboratories.

Rethinking cities can run the danger of upsetting the lives of residents. Planning departments in cities like Boston and Detroit use digital twins to realistically depict the many interconnected systems that make their cities thrive. Digital twins allow planners to test scenarios, observing the likely effects of new designs against such outcomes as traffic congestion, based on real data and known behaviors.

Planners attempt something similar by using 3D models—but a digital twin is much more dynamic than a 3D model. The digital twin's ability to ingest data and predict takes guesswork out of city planning. And machine learning functionality helps planners note patterns that are otherwise invisible. Cities are living, breathing organisms. The people who live in them are the most essential parts of those organisms. Digital twins make residents' lives better by helping planners imagine new visions of urbanism—with designs rooted in reality.

CASE STUDY

Detailed Digital Twin to Enhance Sustainability

City of Uppsala

Situation

Uppsala is Sweden's fastest-growing city. Part of the attraction is the city's reputation as a research center and its ambitious sustainability policy. To handle growth, city planners in Uppsala are creating a new southeastern city district.

Challenge

Early in the planning process, the planning team struggled with the amount of tabular data regarding project requirements. The number and size of spreadsheets grew, and having data in that format made it difficult to engage and collaborate with the multiple city departments involved. It was also difficult to share and conceptualize a physical representation of the complex district plan.

Solution

Planners developed a planning digital twin of the area that depicted what the project would look like and how it would fit into the larger geographic context of the city. The 3D model is built on top of a digital elevation model captured with lidar scanners to show the real topography as well as buildings and trees.

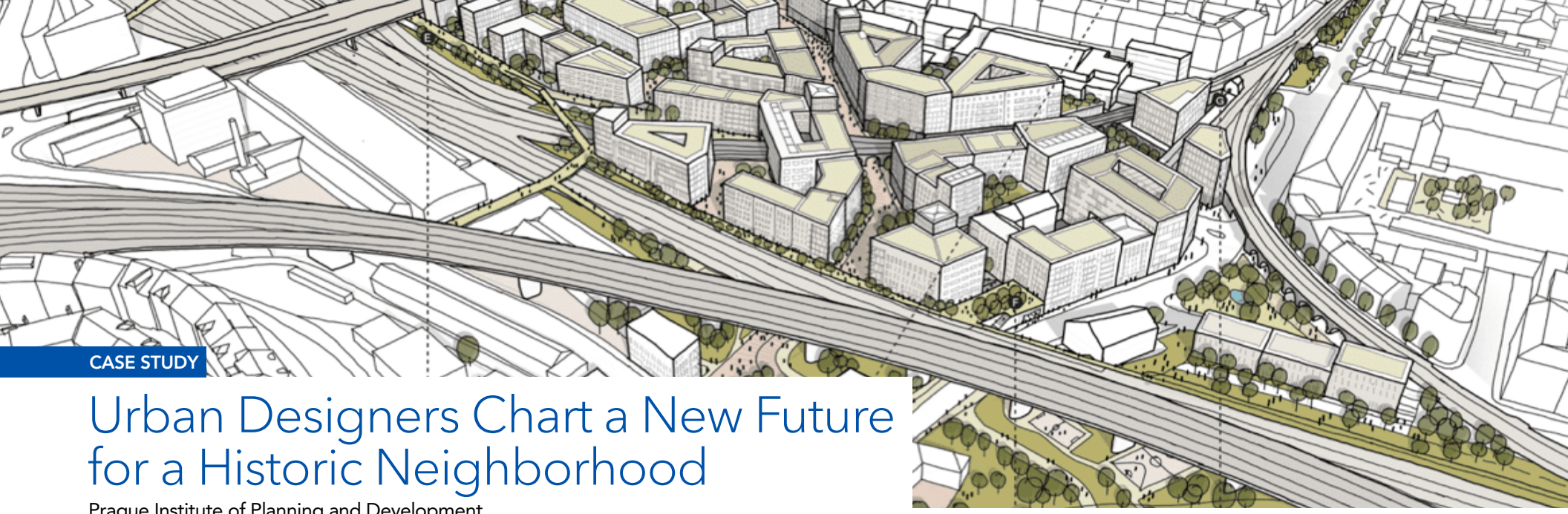
Result

The model provides a way to see the whole of the project. Planners use it to test approaches and reconfigure plans to meet ambitious goals to be fossil-fuel free by 2030 and climate positive by 2050. It provides the means to inform residents and gather feedback. The planning digital twin gives the city and its residents the means to make informed and sustainable decisions.

☞ Read the story.

"Modern GIS uniquely integrates information and data models to create a holistic digital twin. In some cases, GIS itself can be considered a digital twin, but in other cases it enables interconnections to all the different digital models to see the whole from many parts."

–Matt Piper, Esri Director of Global Industry Solutions–Utilities; Telecom; Water; Architecture, Engineering, and Construction; and Infrastructure



CASE STUDY

Urban Designers Chart a New Future for a Historic Neighborhood

Prague Institute of Planning and Development

Situation

Prague is one of the fastest-growing cities in Europe. It's also one of the most vulnerable to climate change. A series of extreme heat events put the city on the pathway to enhance long-term resilience and reduce vulnerability. City planners are working on ways to handle both extreme heat and growth in Florenc, a neighborhood with deep historical ties to the city.

Challenge

The city is committed to preserving Florenc's historic character, but any development had to fit within Prague's commitment to climate change resiliency. Florenc is also one of the city's largest brownfields, a contaminated remnant of the area's industrial past. It's also where the city's modern rail transportation infrastructure comes together, creating a barrier to community cohesion.

Solution

To help guide planning, Prague Institute of Planning and Development (IPR Prague) helped organize Florenc 21, an architectural competition for architects and urban designers from around the world. Each team used the city's digital twin to submit ideas for how to reorient Florenc. The use of the digital twin helped the finalists illustrate how their projects fit within the larger context of the city and the neighborhood.

Result

In keeping with IPR Prague's interest in how Florenc will fare in an era of climate change, the winning team integrated sustainable energy sources and microclimate research into its design. The digital twin helped the planners and designers strike the right balance with new development that addresses climate pressures while improving the lives of residents. It also helped the city planners analyze the submissions and declare a winner.

☞ Read the story.

CASE STUDY

Climate Change Prompts Creation of a National Digital Twin

Grenada Ministry of Agriculture and Lands

Situation

Like many island nations, Grenada is on the front lines of the climate emergency. Increasing heat, intense rainfall, and saltwater intrusion into the water supply and soil now threaten the country's two primary economies—agriculture and tourism. The Grenadan government needed to determine how to continue to grow the country in a way that was sustainable and adaptable to the changing environment.

Challenge

The government adopted a geographic approach to the problem. In 2019, the ministry of agriculture and lands hired Fugro, a company that specializes in geographic and geological data gathering and analysis, to do extensive aerial reconnaissance. The result was a huge trove of information, including high-resolution imagery and a lidar point cloud. With a country-scale amount of data, the ministry then faced the challenge of how to draw conclusions.

continued

Solution

The ministry determined the best way to move forward was to create a digital twin of the nation. With its 20-centimeter resolution, the imagery produced a data-rich, detailed representation of the island. Linking the 3D lidar data brought the imagery into full 3D relief. Officials from the ministry extracted streets and buildings from the visual data to be sorted and quantified. A deep learning model was trained to identify and sort the objects, accomplishing in one day what would otherwise have required up to six months of work.

Result

Officials from the ministry extracted streets and buildings from the visual data and put it into categories. Other categories were created including roads, powerlines, streams and other inland bodies of water, vegetation, and land cover. Working with these categories allowed the ministry to draw conclusions, such as where the country was most vulnerable to landslides and flooding. The digital twin also allows officials to test scenarios, such as the probable results given different amounts of sea level rise.

☞ Read the story.

A Digital Twin Catalogs the Past to Understand the Future

Archaeologists working in Pompeii have pioneered digital twin technology to record digs. Because the act of excavating destroys context, a digital twin is used to record each uncovered artifact and relate it to where it came from.

A fully digital workflow, using iPad Pro devices, gives archaeologists comprehensive documentation of the dig. The data hits the cloud where it's digitized and shared in real time. Collaborators from across the globe comment and offer expert opinions on what's uncovered.

Capturing everything in GIS eases integration into a larger digital twin. The Pompeii Bibliography and Mapping Project provides Pompeii's central archaeology database, which ingests increasing amounts of data. A 3D city model provides the means for anyone to explore archaeological finds, walking virtually through the ancient city and clicking to see details about artifacts found there.

The remarkable digital twin of Pompeii illustrates how the technology can catalog anything. It provides a means to lock assets to reality while also unlocking a sophisticated picture of the past.

Researchers use the Pompeii digital twin to understand not just the past but added dimensions as well. Archaeologists are piecing together the economic and social life there. And there are hopes urban planners will use this knowledge of how people lived in the past to devise a better future.

NETWORK MANAGEMENT DIGITAL TWIN

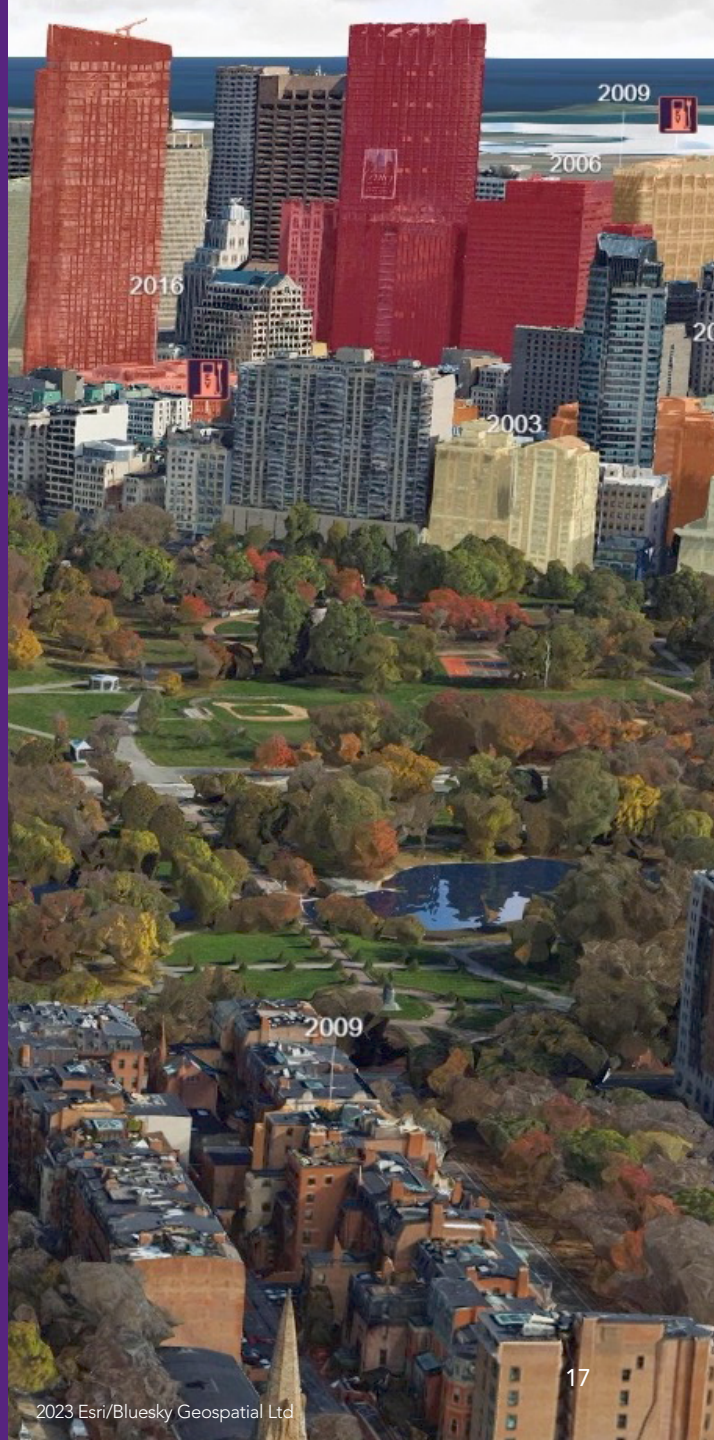
Providing Actionable Information to Sustain Complex Networks

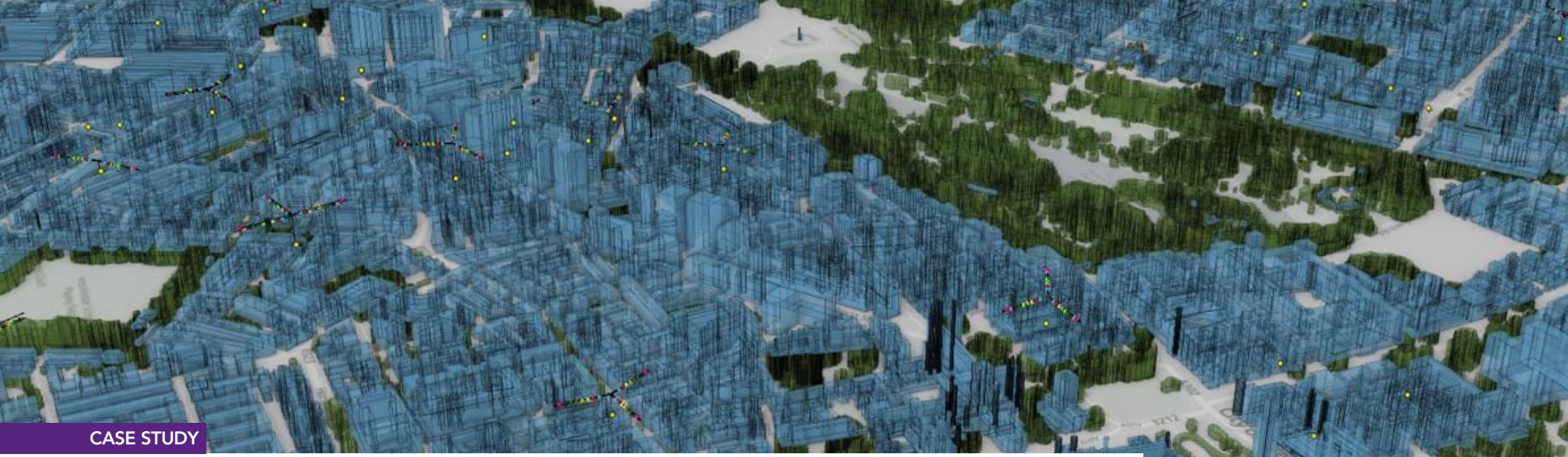
A network management digital twin of complex infrastructure—power, water, telecommunications, transportation—created with GIS contains various levels of detail tied to operations workflows. For engineers, the digital twin enables design and planning informed by accurate reality capture. This allows them to see whole coverage areas and to zoom in to individual assets. A network management digital twin gives infrastructure managers command over massive datasets at every scale and resolution.

Utilities need to provide a safe working environment, deliver reliable service, and support customers. The creation of a digital twin provides tools that are important for every phase of operations, from planning, design, and construction to operations and maintenance. The digital twin provides the backbone for tailored solutions that feed into the whole. And the whole maintains awareness to improve communication, safety, and reliability across the organization.

The network management digital twin allows infrastructure organizations to capture all assets while also modeling operational requirements. In this way, they gain awareness of all assets as well as the attributes of each component. Knowing the function and condition of each component helps ensure a high-performing network. With the digital twin, teams can virtually inspect and plan upgrades. It helps everyone see customers and correlate that awareness to outages. It helps trace features upstream and downstream from any given location. And it helps ferret out problems to decide the best course of action virtually, before crews are sent out.

The digital twin is used to guide constant maintenance and upgrades that strengthen the network and improve customer service. With a dynamic digital twin, a network provider stays on top of plans for developments such as new housing, roads, shopping centers, and sports venues. This helps ensure that the network meets demand wherever there's growth or change.





CASE STUDY

Country-Scale Digital Twin to Engineer a Better Telecommunications Network

Vodafone

Situation

Wireless telecommunications companies create and sell invisible signals. Engineers who build the network have the practice and tools to intuit what they're building. But for other people, the company's signals remain abstract.

Challenge

With the move to 5G, signals travel shorter distances and aren't as strong. Trees and buildings get in the way—resulting in what's called "clutter" in the industry—and more base stations are required. To combat clutter, Vodafone needed a way to see in 3D and model tree growth, with details about seasonal changes that impact signal.

Solution

Vodafone created a digital twin for Britain—representing 245,000 square kilometers—using GIS. The digital twin captures topography, cell towers, and the equipment on each tower. It contains immersive 3D detail, giving anyone at the carrier the ability to see the company's infrastructure, signal strength, and customers. It integrates and correlates network assets, signals, and user knowledge.

Result

For engineers, the digital twin enables signal propagation modeling across coverage areas. The digital twin steers maintenance and upgrades that strengthen signals and increase coverage area. It also enables the company to stay on top of development to ensure that Vodafone's signal is strong wherever demand is growing.

☞ Read the story.

CASE STUDY

Network Digital Twin Guides Brazil Utility's Renewable Energy Expansion

Eletrobras Chesf

Situation

Solution engineers at Eletrobras Chesf, a Brazilian electric utility operator, needed data. Expansion plans and maintenance requirements called for a complete picture of the network. Growing demand for renewable energy created urgency, and environmental requirements posed delays. What Eletrobras Chesf needed was a way to capture its assets and its interface with the natural world.

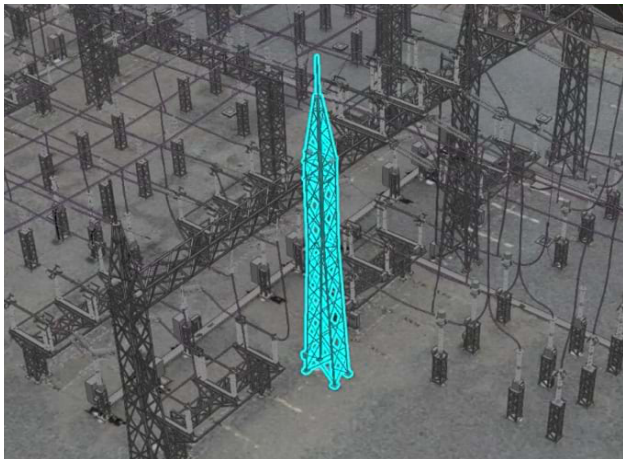
Challenge

The data chief faced a challenge. She knew what data Eletrobras Chesf had about its 12 hydroelectric plants, 14 wind power parks, 136 substations, and 21,000 kilometers of transmission lines. But the data lacked clarity and the ability to be explored or shared.

continued

"We worked hard to show executives that we had to design the process to guarantee that it captures day-to-day activities. Without constant data collecting and maintaining—integrating everything in one place—it wouldn't be a digital twin."

–Valéria Carazzai,
Manager of the Department of
Geotechnology, Eletrobras Chesf



Solution

To fill data gaps, Eletrobras Chesf went all in on reality capture technology. The utility purchased laser equipment for airborne and on-the-ground surveying. Team members captured imagery with drones. They created BIM models of substations. Then they stitched the high-resolution data together in GIS. The resultant PortalGeo system provides a network digital twin for planning, operations, and construction projects.

Result

Eletrobras Chesf now sees all vegetation, bodies of water, exposed soil, buildings, and improvements in 3D in its digital twin. It gives Eletrobras Chesf an added advantage when bidding on new power generation and transmission projects. The data provides the full picture to propose designs and calculate costs, with awareness of constraints.

☞ Read the story.

SCADA—An Early Attempt at Twinning

Supervisory control and data acquisition (SCADA) involves sensors that sample signals and transmit their findings, creating a virtual picture of large distributed systems.

Large electric grids often get the SCADA treatment. A SCADA system captures how and where power is flowing. Many SCADA systems center on automation—for example, redirecting electrical current if sensor readings reach a certain value. But the system also may provide a picture of operations to help staff make decisions.

Is SCADA a form of digital twin?

One argument against that classification is that SCADA provides a snapshot of what is happening right now. That also describes what some digital twins do. But today, the term *digital twin* implies a system that gathers and remembers data, searches for patterns, and reveals hot spots. Instead of gathering signals from sensors, a digital twin draws conclusions. It senses the behavior of the network.

Unlike SCADA, a digital twin may not involve real-time assessments. Its value lies in how it serves as a stand-in for the real thing.

Finally, there is the question of context. SCADA documents a network. In a similar vein, a BIM model of a building is a realistic depiction. But place a BIM model in GIS, and you have context: how the building fits within its environment.

Utilities have adopted network digital twins for added context about impacts to the natural world. That's an awareness they need for regulations. With a digital twin, network operators have the means to plan, design, and operate while keeping impacts to nature in mind.

CASE STUDY

Engaging Residents with Up-to-Date Details about Construction

Maryland Department of Transportation State Highway Administration

Situation

The US relies on a vast network of infrastructure to support its economy and keep its people moving. But an estimated one out of five miles of highways and major roads, along with 45,000 bridges nationwide, need repair. Transportation agencies are addressing these deficiencies to deliver a safe and sustainable network for their customers.

Challenge

Now, as states kick off massive repair and rebuild projects funded by the bipartisan Infrastructure Investment and Jobs Act, the need to keep residents informed of improvements has become essential to day-to-day operations. The six million residents of Maryland need to know what roads are open, when construction will impact their commute, and whether they should take that trip to the shore if it means a five-hour return trip that normally would take an hour.

Solution

The Maryland Department of Transportation State Highway Administration (MDOT SHA) Project Portal includes drone imagery and videos to show the progression of projects, like construction of a bridge from start to finish. Site visitors can explore a map of more than 150 major roadway and bridge projects with up-to-date information including status, detailed plans and objectives, and any closures that may impact travel. Residents can also view project information from recent years and see details for what's coming next.

Result

There is now more efficient communication between MDOT SHA headquarters and the seven district offices. Everyone is more aware of updates on roadway projects. Additionally, the site helps senior leadership answer questions from constituents.

☞ Read the story.

OPERATIONS DIGITAL TWIN

Achieving Contextual Awareness to Improve Operations and Maintenance

The operations digital twin contains a phenomenal level of detail. Integrated GIS, BIM, and high-resolution imagery data provides a robust system of record of physical assets. This foundation is then augmented with numerous details about items that must be maintained.

Moving assets are added to manage fleets. Equipment is tracked to find the nearest asset when it's needed. Materials too can be logged, as can the hard-working things that need regular maintenance or replacing like pumps or lightbulbs.

Together these types of data provide a digital twin that becomes the source of truth for the organization. It makes actionable the flood of data and information that companies collect.

This ability for a digital twin to capture institutional knowledge comes at a time when operations veterans are retiring en masse. A digital twin provides backup, capturing collective wisdom before knowledge walks out the door.

With the detailed digital twin, teams conduct maintenance and plan upgrades. They see such details as the manufacturer and model number of a pump, when it was installed, how it should be maintained, its record of performance, and where all similar pumps are located. The digital twin quickly becomes the means to guide workers to each task. It also integrates reality within other operations systems for tasks such as keeping an eye on energy or water use.

Facility employees have commented that the integration helps them proactively plan their day. For instance, when it's time for HVAC filter replacements, they query how many are needed, ensure that there is sufficient stock, and decide how to transport replacements. Maintenance crews isolate a valve or switch virtually, then walk right to it.

The same digital twin is used to perform spatial and temporal analysis to answer questions and forecast events. Operational digital twins help infrastructure-based companies become more efficient, provide better experiences for their customers, and protect and expand revenue streams.

CASE STUDY

A Digital Twin Fuels Record Expansion at Vail Ski Resort

Vail Ski Resort

Situation

The director of land development at Vail Ski Resort spent nearly four decades planning chairlifts, trails, and restaurants at North America's most popular ski resort. Yet he had never encountered a project of such scope and urgency as that of expanding snowmaking to deal with precipitation variability and climate change.

Challenge

Vail Ski Resort is massive. It's the second-largest single-mountain ski operation in the United States, spanning more than 5,300 acres. In 2018, Vail Ski Resort's management decided to expand snowmaking with the goal of making it operational before the 2019 ski season. The effort involved installing 19 miles of pipes for air and water, 25 transformers, 421 snow guns, and more.

Solution

The mountain's digital twin—capturing asset locations in a database and leveraging the ability of GIS technology to create replicas of both natural and built environments—helped staff get a handle on the project. The operations digital twin uses GIS to generate smart maps for employees running everyday operations ranging from snowmaking to snow grooming.

Result

A manager continuously monitors Vail Ski Resort's operations digital twin—the map of the mountain's compressors, pumps, water and air valves, snow guns, and other hardware involved in the mountain's maintenance. Staff have a graphical view, and with a couple of mouse clicks they can make adjustments to optimize the system.

☞ Read the story.

"Our goal is to use all this technology and make it easier for us when we're building and easier for the operator to run and maintain all this equipment long term."

–Bill Kennedy, Director of Land Development, Vail Ski Resort

CASE STUDY

A New Awareness to Improve Wastewater Operations

Hampton Roads Sanitation District

Situation

In the Tidewater region of Virginia, the land lies low, and rising sea levels pose a growing challenge. Hampton Roads Sanitation District (HRSD), the region's wastewater treatment operator, serves 1.7 million people across 20 cities. To compound the challenge of sea-level rise, pumping of groundwater was making the land subside. HRSD set out to pump treated water back underground to arrest this sinking.

Challenge

HRSD needed a way to monitor the treatment of water and see the impacts of groundwater recharge. The new project was key to minimizing stormwater events and combating saltwater contamination. HRSD had to prove it was a workable strategy.

Solution

HRSD combined BIM designs with GIS maps, workflows, and analysis. Together these inputs create a feature-rich operations model. It affords a higher level of operational intelligence to capture plans and as-built drawings alongside real-time awareness of how the facility is performing.

Result

Facility managers and construction crews access the model by wearing virtual reality headsets to see where an asset needs to be placed and how to maintain it. The digital twin provides an ideal training platform for new staff. Additionally, HRSD's 20 years of data have been used to conduct hot spot analysis to see the primary areas of failure, understand what's causing failures, and figure out what needs to be done with all the other pipes that have similar characteristics.

☞ Read the story.

"We've achieved situational awareness. We now would like to simulate our system, looking at the behavior of the infrastructure and knowing, if I open a valve and change a process, what are the effects to the downstream process?"

–Anas Malkawi, Chief of Asset Management, HRSD

CASE STUDY

Creating a GIS-Based Digital Twin of the Service Supply Chain

Cisco

Situation

Cisco repairs and replaces products ranging from servers in data centers and networking switches, to videoconferencing systems in offices and executive boardrooms. To accomplish this, Cisco maintains a supply chain that delivers parts and service to millions of customer sites in more than 130 countries—often within two hours of a customer's request.

Challenge

Cisco needed a way to deliver fast and effective technical support with an awareness of each location and the web of suppliers, contractors, and employees to carry out the work. The company needed a way to maintain high efficiency and high levels of customer satisfaction.

continued

"Cisco's use of GIS has yielded several benefits: more efficient parts routing, smarter warehouse locations, optimized inventory, and—most important—the ability to better meet a wider range of customer needs."

–Warner de Gooijer, Lead of the Innovation & Incubation Office, Services & Logistics Group, Cisco

Solution

Cisco created a digital twin called the Service Delivery Insights Platform (SDIP), a central nervous system connecting logistics, field services, planning, order management, and sales support. Fueled by a set of business rules and GIS-based location intelligence, SDIP provides near real-time awareness, allowing it to dispatch spare parts and technicians from the most appropriate warehouse and engineer base.

Result

The transformation of Cisco's service supply chain from a spreadsheet-based process to a near real-time digital twin represents an investment in reliable data, intelligent systems, and customers. SDIP improves territory accuracy and visibility by creating a reliable single source of truth for Cisco's global service supply chain. The system automatically assigns new customers to the appropriate depot and adjusts assignments when warehouses are relocated or configurations are altered.

☞ Read the story.

The Holy Grail of IT—A Digital Twin of People, Process, Tech

Most CIOs of large corporations know their servers, services, apps, and users, yet they lack knowledge of how they integrate or are interrelated. When a server, service, or app goes down, it's hard to determine the affected people and departments.

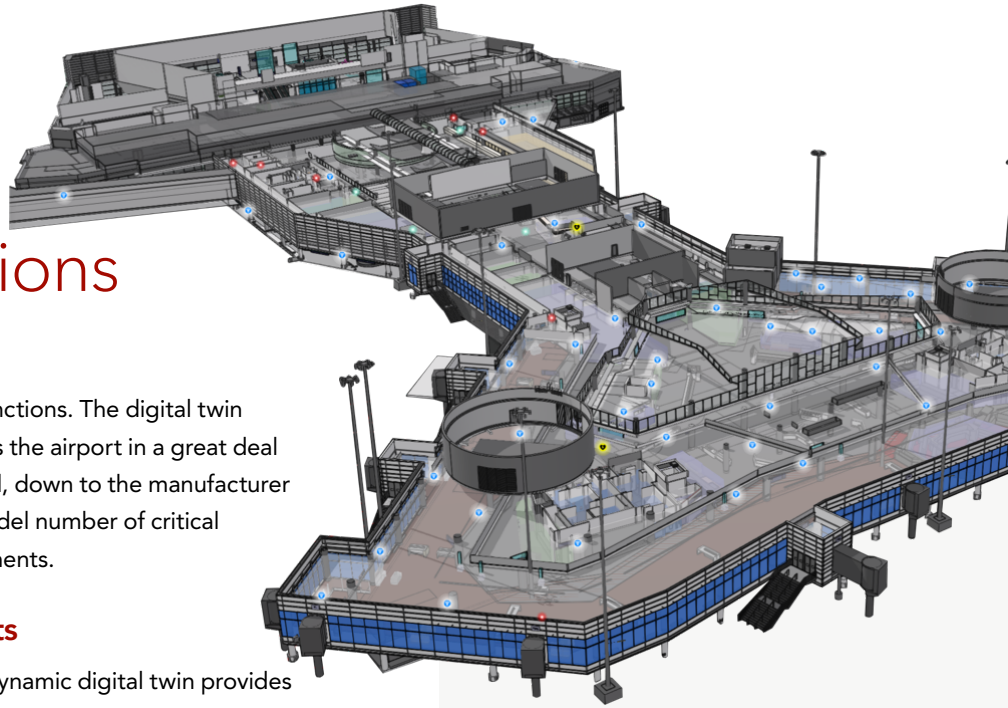
Innovators apply an operations digital twin to visualize IT infrastructure, workflows, and stakeholders. CIOs with an unobstructed view into physical and digital infrastructure are ready for any crisis. If a cyberattack occurs, they know the employees and customers affected. In the event of extreme weather, CIOs know what data centers to harden, replicate, or take offline.

If servers and apps need routine maintenance, CIOs know where things will go offline and whom to alert. An operations digital twin lets them see the physical and digital together. It gives CIOs and other executives critical awareness. An operational digital twin ensures business continuity in a volatile world.

CASE STUDY

Dynamic Twin Transforms Operations

San Francisco International Airport



Situation

San Francisco International Airport (SFO) has been at the forefront of modernization. It was an early adopter of GIS as part of the Federal Aviation Administration's mandate to use the technology to manage horizontal infrastructure—runways, taxiways, and pavement. SFO saw the results and adopted a vision to expand GIS use to encompass the majority of airport operations.

Challenge

This desire to expand the use of GIS at SFO reflected an understanding that airports are enormously complex environments. Like cities, they function by means of many systems operating separately while remaining connected to each other. The different types of traffic—cars dropping off and picking up passengers; pedestrians going through the concourses and gates; and, of course, the aircraft that takes on and delivers passengers—all affect the others. Furthermore, they are all linked to the continued maintenance of the airport's systems, everything from HVAC and elevators to rail links to terminals—these all must be operating to move people and goods efficiently. SFO wanted a way to integrate its systems into one digital environment.

Solution

SFO built a dynamic digital twin using GIS to incorporate other technologies such as BIM models of construction plans and work order management systems that capture maintenance details. SFO's dynamic digital twin reflects the dimensions of both the interior and exterior of the airport's facilities as well as the activities of most of its assets, providing a continually updated rendering of spaces as well as the systems that contribute to their functions. The digital twin portrays the airport in a great deal of detail, down to the manufacturer and model number of critical components.

Results

SFO's dynamic digital twin provides an ongoing digital alignment of the virtual and real-world environments—a window of entry into the airport's infrastructure—allowing managers to monitor how components and systems are functioning. The integration has been essential to pulling off the airport's ambitious and transformative $7 billion renovation, modernizing it through the addition of a new hotel, revamping two terminals, adding parking, and creating tighter transit connections across the region.

☞ Read the story.

"It's about delivering advanced knowledge to the user and the passenger so they feel more in control of the experience going through the airport."

–Josephine Young,
Director of Infrastructure Information Management at SFO

ENVIRONMENTAL DIGITAL TWIN

Protecting Biodiversity and Fueling Scientific Discovery

The geospatial digital twin concept encompasses more than just engineered systems. The complexity and uncertainties of the natural world require interdisciplinary attention. Scientists and land managers use GIS to compile layers of data about flora, fauna, land features, archaeology, infrastructure, and more. These layers create the foundation of an environmental digital twin: an inventory of existing conditions, ecological systems, and earth processes.

With an environmental digital twin, land managers and conservationists can understand the landscape. They can visualize it. And they can use it to run models that forecast what it will look like in the future, given human-caused and natural impacts. The digital twin provides a holistic perspective on biodiversity considerations, merging social, cultural, economic, and other dimensions of the place.

The pressure of climate change has created urgency. It has fostered new disciplines and bred new models aimed at understanding ecosystem services. This attention combines with an explosion of data captured at higher resolution and with more frequency than ever. A digital twin provides the right platform for data and process to come together. An environmental digital twin creates knowledge integration and fosters sharing across disciplines.

An environmental digital twin isn't just for science professionals. Resource-based organizations benefit from the concept as well. For the production forest or agriculture, the environmental digital twin enhances timber and crop yields. But foresters and farmers focus on carbon sequestration yields as well. Carbon farming isn't far off. That revenue will fund environmental digital twins that balance yields with carbon outcomes. The future focus will be on optimizing the resource as well as the ecosystem benefits.

There are many exciting possible outcomes from environmental digital twins. But the complexity can't be discounted. The range of scales and interconnectedness are mind-boggling. The first forays will be specific. They will tackle small ecosystems and certain species (types of trees, crops, endangered species).

Valuing nature provides an added focus for environmental digital twins. They will quantify such things as the water quality enhancements that forests provide or the farming practices that optimize soil health and sequestration capacity. An environmental digital twin provides the means to address complex questions. These digital twins will grow organically to encompass ever larger connections and interconnections to weave together understanding of entire ecosystems.

CASE STUDY

Protecting Point Conception, California—Maps and Sensors Aid Science

Point Conception Institute and The Nature Conservancy

Situation

Point Conception sits where the Southern California coastline bends north, and so marks a major ecological transition between northern and southern ecoregions. The area is a great example of an ecotone, with flora and fauna from both areas that intermix and create an abundance of species not found in other places. California is the most biodiverse US state, and the Point Conception region is among the nation's most biodiverse places.

Challenge

A 25,000-acre property at the point became available. The site, formerly the Cojo-Jalama Ranches, had been slated for development. However, The Nature Conservancy was able to purchase the property, putting this land on the path of preservation. The question then became how to preserve it.

Solution

The Nature Conservancy has established the Point Conception Institute to harness the power of open science to tackle urgent challenges related to climate change and biodiversity loss. The institute fosters diverse research collaborations with data stewardship and sharing and applies innovative technical and geospatial solutions.

Result

Scientists have already compiled 90 layers of GIS data to capture details about the land including its archaeology, wildlife, and vegetation. These layers create the foundation of a digital twin of the landscape that lives within GIS. The digital twin is instrumental in helping land managers inventory existing conditions, identify relationships between the conditions that define ecological systems, and simulate landscape processes.

☞ Read the story.

"There's a real opportunity to develop a new model for conservation, using open science to establish legacy datasets that can be brought together with other data streams to create a true interdisciplinary collaborative effort."

–Mark Reynolds, Director, Point Conception Institute

CASE STUDY

Smart Maps Help Maine Foresters Manage “Magic Forest”

Seven Islands Land Company

Situation

The North Woods of Maine is a special place that contains a complex mix of trees that needs varied harvest practices to maintain the species balance. The diversity of terrain and tree products makes every day interesting for Seven Islands Land Company foresters.

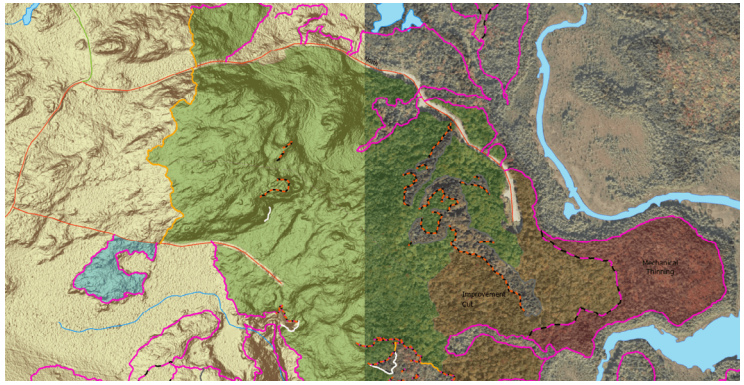
Challenge

Lately, climate extremes have made it very difficult for foresters. They like the winter months when boggy areas freeze and there aren’t biting bugs. But dramatic 80-degree shifts in temperature—swinging from -20˚F to 60˚F and changing snow to rain—make it tough for trees and foresters to keep up.

continued

"Many of these stands are just a wall of green, with vegetation from 1 inch aboveground to 80 feet. We map it to create a parcel fabric that reflects the many different types of trees and stands and their maturity."

–Nalbert Tero, Operations Forester, Seven Islands Land Company



Solution

To adapt, Seven Islands deploys GIS—in the forest and the office—to monitor road conditions and the ecological pressures on trees. The forester's job is to manage each species sustainably and make sure demand for a specific product doesn't lead to overcutting. The foresters use GIS to create an environment digital twin with an inventory of trees—mapping species, age, and quality. These details all relate to specific wood products. And foresters catalog their work, from thinning to spraying to cutting to planting.

Result

The environment digital twin gives foresters an intimate knowledge of the forest as well as the ability to see and catalog each stand, a contiguous community of trees of similar composition, age, size, and structure. The environment digital twin gives Seven Islands the means to conduct viewshed analyses to know how a clear-cut will be seen from the road or popular recreation spots; look at animal and plant patterns to see if plan modification is needed; and take a watershed view of streams to protect water resources.

☞ Read the story.

Digital Twins Encourage Interdisciplinary Research

With GIS, datasets come together to fuse knowledge of the environment and everything that moves and changes in the landscape.

GIS provides an open platform to track the behavior of animals and their interactions. Scientists explore migrations or seasonal changes. Archaeologists use digital twins to peel back layers of the past. Field researchers extend their discoveries to far-flung networks. Anyone can contribute to fundamental research and add knowledge about collected data.

An open digital twin provides the foundation for open science due to its ability to capture measurement, incorporate models, and dive deep on analytics. It encompasses all manner of physical, natural, biological, and social science to see how things are and how they relate to each other.

Digital twins provide new methods of research. The long, drawn-out process of scientific research needs to be sped up. Instead of peer review and publication, research would shift to open sharing of data, models, and theories. A digital twin meets the urgent need for evidence-based and interdisciplinary guidance. Digital twins are needed now more than ever.

CONCLUSION

Digital twins first emerged in the manufacturing world. They provided ways to track the functioning of machinery, down to the level of the smallest components. This information was not in real time. It was presented after the fact to help managers and technicians check the functioning of systems and understand overall operations.

Since that time, the sophistication of digital twins has increased. But the change is not merely about metrics like improved graphics or processing power. What has changed the most is context as an element of digital twins. They are no longer documents of performance considered in a vacuum. Rather, they depict how actions intersect and relate to create a picture of the whole.

Geospatial digital twins offer something that approaches maximum contextual awareness. By helping people visualize the intermixing of data flows, these digital twins connect abstract data with concrete experience.

By answering the constantly shifting question of "where," geospatial digital twins are the culmination of contextual understanding. They bring together data, operations, location intelligence, and artificial intelligence. They understand the present. They can help people adapt quickly in moments of crisis. They can use the present to predict or—perhaps better yet—imagine the future.

About Esri

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 hundreds of thousands of organizations globally, including Fortune 500 companies, government agencies, nonprofit institutions, 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 technology and analytics, Esri engineers the most innovative solutions that leverage a geographic approach to solving some of the world's most complex problems by placing them in the crucial context of location.

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