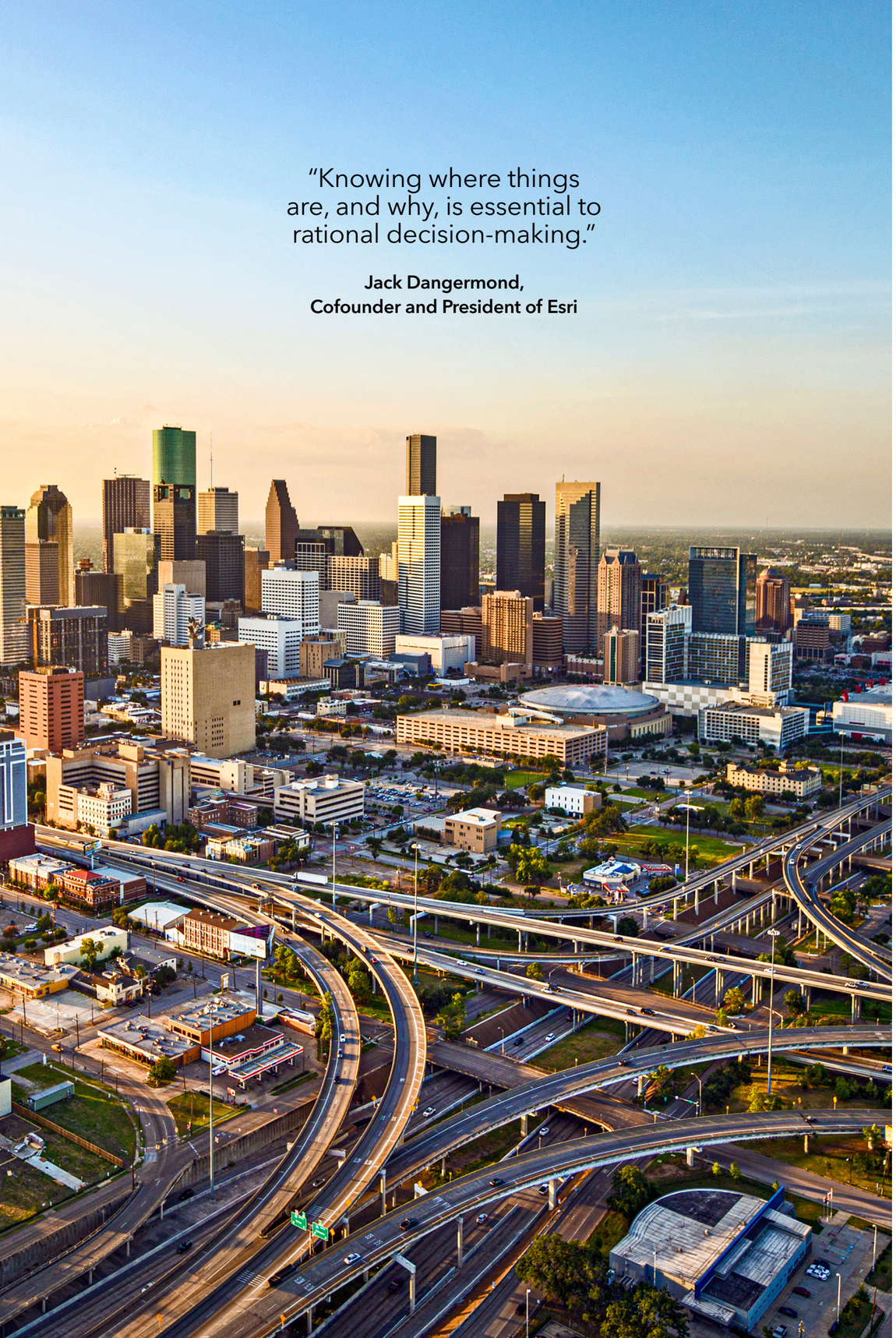
esri

The Spatial Advantage

How analysts and data scientists are using spatial analytics to deliver insights with instant value.



WHAT'S INSIDE

Executive Summary: It's Not Just Who or What, but *Where*

You're in the problem-solving business, constantly asking questions and seeking the answers in data. Most often, *where* questions are foundational.

Where are my suppliers? Where are my competitors? Where are my assets? Where are my best customers and others like them? Where are the risks? Where are the people I should hire? Where might climate change impact my organization next?

Questions like these—spatial questions—require spatial answers.

Yet, many organizations haven't recognized how essential geography and spatial analytics are for making informed decisions.

Through modern mapping technology such as Esri's geographic information system (GIS) software ArcGIS®, spatial analysis bridges enterprise systems to bring location awareness and spatial problem-solving across departments.

ArcGIS has been recognized by market research firms, including Forrester, which gave Esri its highest ranking in spatial visualization and analytics, noting, "the key strength of Esri's platform is its complete set of location intelligence capabilities."

This ebook is your guide to real-world spatial analytics in action and to the questions best answered through spatial analysis.

> Spatial analytics can be an important source of innovation, helping solve problems across operations, marketing, risk, and beyond. It may even be instrumental in organization-wide transformation, changing how everyday business and operations are conducted.
>
> **from "The Rise of Spatial Thinking,"**
> ***Deloitte Insights***

Unique Spatial Analytic Pathways

Humans have long used maps to describe the location of physical features and to aid wayfinding. Simple metrics showed the size of areas and distances from one location to the next. Early attempts to use maps for further analysis involved layers of data printed on clear sheets, overlaid on the map to display correlations.

Those data layers formed the foundation of modern spatial analysis. Only now, they're digital and created through location intelligence technology. Layers deliver information about weather, terrain, and natural resources. Layers mark the path of roads and utility networks and the sites of buildings. Layers tell stories about people, including their behaviors and characteristics.

Moving beyond visualization of data layers, spatial analysis entails classifying and clustering data to understand circumstances and events on a human scale. Quantifying geography involves mathematical models and algorithms. With location intelligence software, cloud computing, and AI, you can quickly arrive at the answers to your *where* questions, with even more dimension.

A few key concepts help illustrate the many dimensions, scales, and possibilities of spatial analysis.

Spatial Statistics analyzes distributions, patterns, processes, and relationships. See the median, mean, and standard deviation of values—like home prices or product sales—across a region. Identify clusters, outliers, and spatial trends. Use spatial modeling to describe relationships with a series or sequence of steps to predict future values, understand causal patterns, and weigh options.

Tapestry Psychographic Segmentation is a market research approach that starts with demographics, providing details about people and population trends. It finds patterns in consumer decisions based on purchase history and online activity and identifies geographic areas where people share traits like income or household size. By finding places with profiles similar to your best customers, you can pinpoint new markets.

Movement Data pulls together anonymized mobile phone data to provide an accurate pulse of human mobility, both day and night, including store visits and traffic. Esri partners with movement data providers to help businesses make location-based decisions like what store hours to keep and how to reach potential customers based on their patterns of movement.

Social Equity Analysis enables businesses and governments to focus investments on serving people and neighborhoods that historically lack opportunities, like access to fair lending or clean air. Spatial analysis provides the means to consider community characteristics and generate an equity analysis index. The result is a map that shows where need is highest and where investments can make the most difference.

GeoAI is the application of artificial intelligence, such as deep learning and machine learning, fused with geospatial data, science, and technology. GeoAI swiftly sifts through volumes of data including imagery, using algorithms that automate analysis to find answers to not only *where* but also *where now*. GeoAI's ability to monitor change and make predictions is helping multiple industries stay ahead.

Imagery collected from satellites, aircraft, and drones is becoming more widely available, and companies are using it for monitoring and forecasting. They are looking at fluctuations in weather and consumer demand to take near-term action based on long-term events. Imagery can also be used to fill in data gaps without having to conduct in-person surveys. Want to see historical store traffic in December? Calling up historical imagery of how full the parking lot was provided a clear picture.

Digital Twin describes any virtual system that mirrors the objects, movements, and relationships of its real-life counterpart to simplify the complexity of, for example, smart cities and critical infrastructure projects such as a new subway line. A digital twin displays the past, present, and future of a facility or network, allowing for analysis, simulation, and predictive modeling. Future scenarios can be tested and iterated without disrupting real-life operations.

Reaching Customers Where They Are: Answering Critical Questions with Location Intelligence

Businesses need to reach customers in person through well-located storefronts but also on their devices while ensuring a seamless experience from ordering to fulfillment.

Omnichannel adds complexity to operations. But online transactions also add a bevy of data for businesses to understand consumer habits and expectations—and to meet customer needs wherever they shop.

Data scientists for smart omnichannel retailers are looking to spatial analytics and location intelligence to reveal patterns and trends in an ever-growing pool of data and data types.

Location intelligence has long been used for traditional site suitability and retail network optimization. Modern tools and data sources empower businesses to make even more strategic investments, whether opening a new physical location, closing others, or determining the best place for a distribution hub.

Spatial analytics helps identify areas that have been underserved for a business's particular products and services or reveal collocational opportunities next to complementary businesses. Anonymized movement data can assist here, too, by showing where and how people shop.

When analysts filter streams of disparate data to reveal customer behavior, they make sense of who their organizations want and need to reach.

BANKING/FINANCE USE CASE

Pinpointing New Bank Branches

In an omnichannel world, analysts at financial firms are trying to grow their customer base through in-person and online banking. About 43 percent of people used mobile banking in 2021 compared to just 15 percent in 2017, according to the Federal Deposit Insurance Corporation. That means financial institutions must appeal to customers who have never entered a bank branch, those who do all their banking in person, and everyone in between.

For one of the top 10 US banks, the use of spatial analysis for strategic customer outreach comes down to curiosity about when and where people bank. In the past, the bank's executives would have scanned demographic research when choosing the best locations for new branches. Now, they turn to spatial analysis for a more scientific approach.

Using the location intelligence gathered from spatial analysis to pinpoint the best places for new bank branches, analysts have created models that go so far as to accurately predict deposits for prospective locations.

The same location-based tools are uncovering better ways to serve the bank's online customers. Those customers may have opened accounts with little knowledge of what would be the best fit. Then they found themselves overdrawn or wanting to close accounts they weren't using. Now, the financial institution can connect those customers to their nearest branch for personalized service.

Banks and credit unions are increasing their commitments to social responsibility, locating new branches in underserved communities, and giving more loans to small businesses owned by people of color. Social equity analysis can also help institutions like the top US bank mentioned here reduce harm and create opportunities for good.

By providing insights for more effective omnichannel and equitable customer service and outreach, location intelligence has had a direct impact on the bank's business performance and customer experience.

Here's how spatial analysis answered the bank's critical questions.

Best location to fit the criteria: Where is the best place for a new bank branch?
The first step involves defining goals and constraints (accessibility, demographics, costs). Then, each criterion can be weighted according to priority. A spatial overlay process puts criteria on a map to find locations where the most important characteristics intersect. Analysts and decision-makers can then consider trade-offs and practicality in selecting the optimal location. If you're working with uncertain or imprecise data, spatial techniques can clean, integrate, and normalize your data.

Attraction and decay: How will a certain location attract or divert customers?
Predictive models can help visualize a new location's potential to draw in customers, as well as the cannibalization effect it may have on existing branches. Factors like population or existing economic activity in the area can be modeled against other locations' performance for accurate estimates. Consumer movement analysis reveals popular places that deserve higher weighting since we're naturally drawn to the places we frequent already. The rate of attraction to a particular location, generally speaking, is relative to distance. The further the distance, the less gravitational pull. The use of gravity models can show the relationships between travel distances and customer bases to predict demand.

Detecting and quantifying patterns: Where are the significant hot spots, anomalies, and outliers?
Determining how best to serve customers requires understanding where they live and work, as well as less tangible characteristics like demographics, human movement, weather, or transit systems. Take the customer that does most of their banking online—could they be avoiding their local branch due to persistent traffic congestion? What about the customer who lacks a nearby branch? Are they an outlier in the area, or would more customers be served by a new location? Finding clusters or exceptions in data about people and places brings locations to life for more informed decision-making.

Halo Forecasting with AI: A Major Leap in Retail Planning

For years, large retailers have observed that online sales don't always detract from sales made in their brick-and-mortar stores. On the contrary, digital sales often increase in geographic areas near a store's physical location. The industry calls this mutually beneficial relationship the *halo effect*.

The halo effect is not a sure thing. Retailers can optimize the halo effect with smart store siting. That means considering many types of factors, including data on in-store and online sales, detailed demographics, and the complex spatial relationships between proposed sites and surrounding markets.

Effective halo forecasting requires judicious application of GeoAI. The first step is to use spatial analytics to quantify proximity. Using distance measurements such as drive times in conjunction with demographic and consumer preference data, you can calculate expected foot traffic and revenue at possible store locations. Then, GeoAI can support close analysis of consumer spending through AI-powered algorithms and predictive modeling techniques that yield an accurate forecast of online sales. The results are then displayed on a map, showing which physical locations are projected to maximize both in-store and online sales.

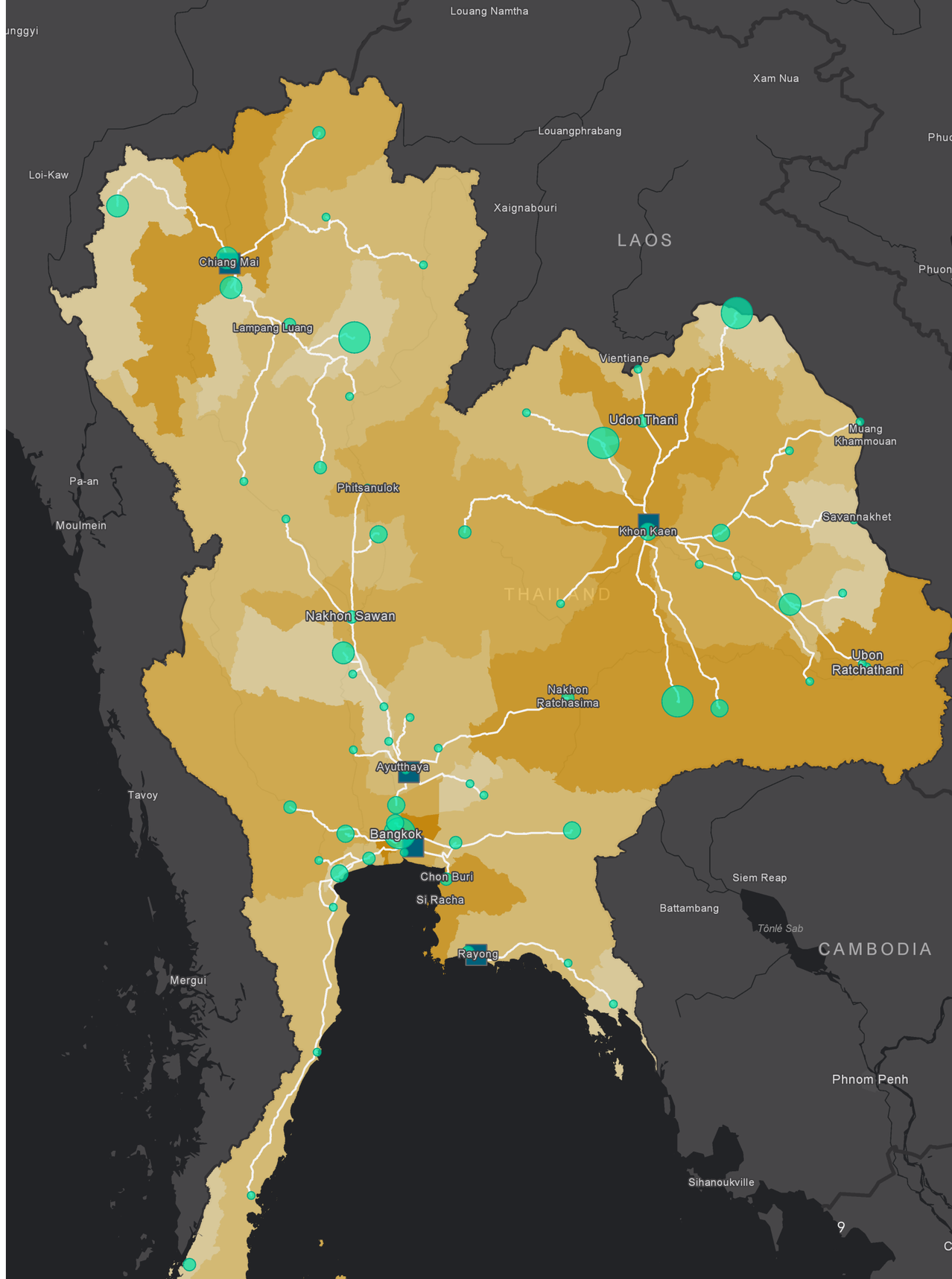
Making Supply Chain Decisions: Integrating Spatial Data with Enterprise Systems and Processes

Those new cars on the lot . . . they're the carefully choreographed culmination of thousands of parts coming together from around the world. For virtually any consumer good, key resources need to be precisely coordinated, often dodging global threats—weather, pandemics, or political unrest—that risk a broken link in the supply chain.

When disruption does happen, companies benefit from cross-departmental visibility into their entire chain of suppliers. That knowledge keeps operations flowing and identifies alternative sources, allowing a company to zig and zag when necessary.

The proliferation of sensors, from smartphones to drones to IoT devices, as well as survey tools, means supply chain data is more accessible than ever. This makes it easier to manage distributed assets and pinpoint the places to take action. Helping make sense of it all is a one-stop spatial solution—spatial analytics—that collects, processes, analyzes, and visualizes location-based data, integrating with existing enterprise tech and open-source tools and absorbing data lakes.

The visibility and traceability, achieved by taking a geographic approach to supply chain management, have wide-reaching advantages—agility, sustainability, environmental responsibility, and cost efficiency. All it takes is an insightful and inquisitive employee or team with the right tools to learn more about where supplies are coming and going.



MANUFACTURING USE CASE

How a Clothing Pioneer Became a Data Analytics Powerhouse

Executives need analysis done thoughtfully, but quickly, because opportunities won't last. And the analysis needs to tell a persuasive story. One global garment manufacturer turned to its data science team to find a competitive edge by streamlining the company's supply chain.

The team provided analysis and simulations investigating whether it would be more beneficial to open a new distribution center or redistribute products to existing centers. To do so, the team visualized the company's supply path from producers to processors to wholesalers and the connections between them. An agent-based simulation model focused on the relevant details.

On a map, the company's decision-makers were able to see the locations of existing and prospective distribution centers and transportation routes. The model considered other factors including distances, overhead costs, and total shipments. After running multiple simulations through Esri's modeling software, the company determined it could save 20 percent on shipping costs by redistributing its products to existing distribution centers.

Here's how spatial analysis answers the manufacturer's critical questions

Location-allocation models: What supply center is best situated to meet a factory's demand?
Whether you want to minimize travel costs or find the most direct routes, location-allocation analysis finds the best point B for a cluster of point As. This approach evaluates a series of locations, like existing or planned supply centers, against nearby demand points, like factories or warehouses. Spatial factors could include transportation options (street, road, highway, rail, port), transportation costs, proximity or travel time, or the amount of supply available at each location. Modeling potential hubs and routes consolidates the flow of goods to exploit economies of scale and reduce transportation costs.

Determining overlapping relationships in space and time: What's the best time to ship a container of finished goods?
Whether something is close, visible, or accessible to something else often depends on timing. Factors like traffic, weather, or service disruptions can turn a short spatial route into a lengthy temporal one. Bringing time into logistics analysis is therefore critical to finding optimal routes. With spatiotemporal analysis, you can determine where and when an object (like a container ship or delivery truck) may intersect with certain conditions (like a storm or roadwork).

Finding the best route, path, or corridor: What is the best shipping route?
Cost surfaces are a type of raster data model with cell values that indicate how costly it is to traverse an area in terms of time, money, effort, or safety. Values can be calculated using factors like water depth, weather patterns, airspace availability, or geopolitical boundaries. Assessing these values over a range of cells is called *cost-distance analysis,* which ultimately reveals the safest, fastest, least expensive, or otherwise most viable paths between points.

Tessellation Helps See Patterns in Data

Imagine a tiled floor. On each tile, there's a stack of files—information bucketed into equal tile-sized areas rather than scattered as individual pages.

When it comes to managing large volumes and varieties of spatial data, this same organizational structure is achieved digitally through a process called *tessellation.* In this technique, maps are sectioned into grids, and layers of data are stacked within each cell. It's a deceptively simple yet powerful way to see the spatial distribution of data, identify patterns, and measure distances between points of interest.

Tessellation is a popular tool for tasks like market analysis or site selection that rely on understanding where key data overlaps or diverges. Grid cells with more high-income earners, for instance, show the best markets for luxury goods. Cells with a low concentration of competitor locations may indicate an area with a service gap you can fill. Using tessellation, you can quickly see who or what exists in a given cell-sized area and decide instantly whether a location is worth investigating further.

Deciding Routing and Logistics: Data Analysis in Real Time

Using spatial analytics, logistics companies not only automate the best next move but also quantify potential delays and workarounds to keep everything moving *just in time.*

Optimized delivery routes reduce fuel and vehicle maintenance costs, lower emissions, improve safety, and enhance customer satisfaction. As some shippers have noted, eliminating a mile for each driver every day results in millions of dollars saved when you operate on a global scale.

Spatial analytics can be used to plan routes that factor in real-time inputs such as traffic, road closures, and multiple deliveries. Real-time tracking lets drivers, customers, and managers see progress to make sure the delivery is on time and going to the correct address. *Geofencing*—placing virtual boundaries around areas—can help prevent drivers from entering restricted zones.

GeoAI can integrate sensor feeds from vehicles, drivers, aircraft, ships, ports, traffic cameras, and weather stations to quickly provide a holistic view. This allows logistics companies to monitor, analyze, and revise routes in real time. Even the largest volumes of data can be analyzed and, in many cases, trained to detect risks before unnecessary disruptions occur.

LOGISTICS/SUPPLY CHAIN USE CASE

Shipper Strengthens Customer Connection with Spatial Analytics

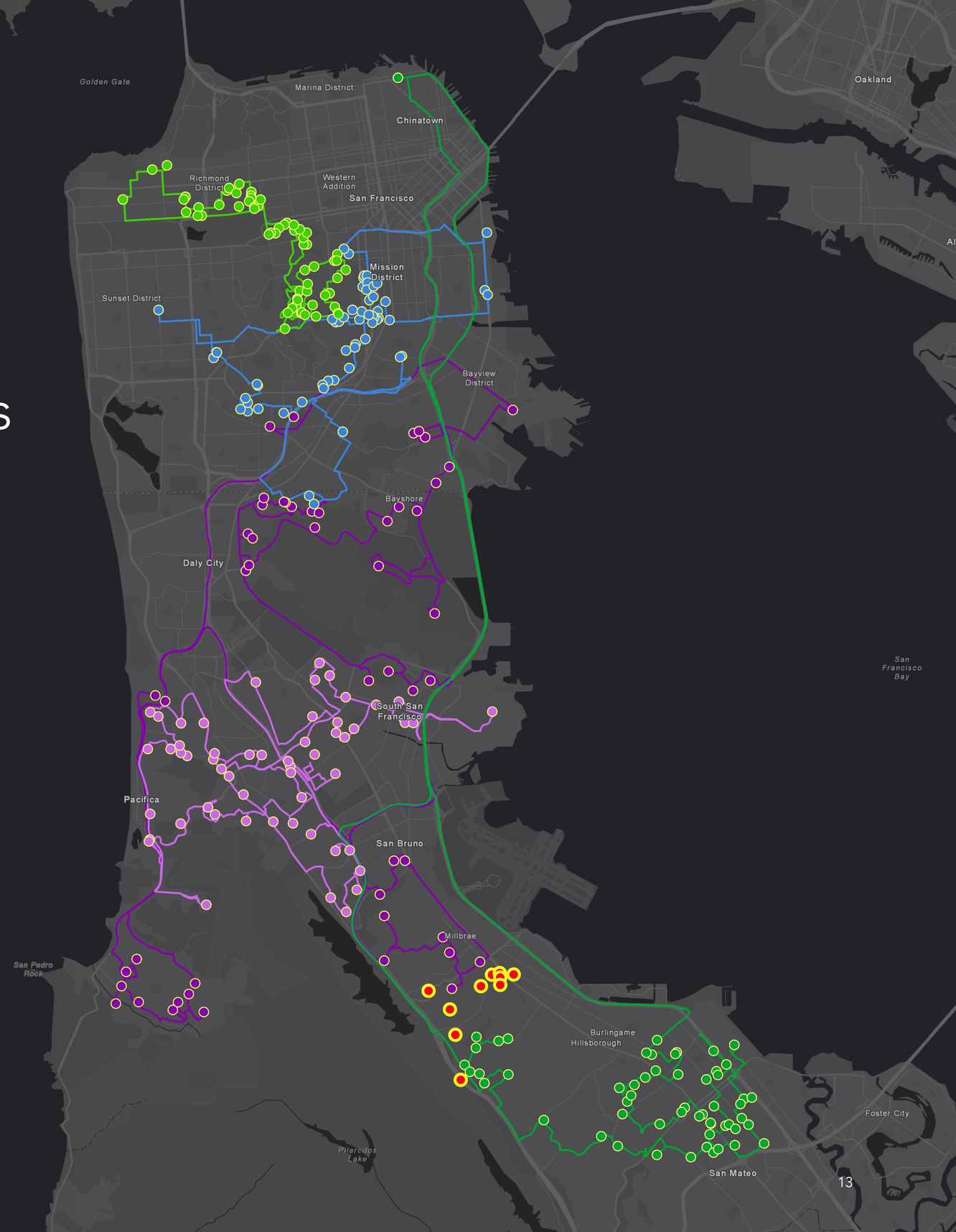
There are countless questions to consider when designing optimal routes and sequences of stops and making on-the-fly decisions based on real-world traffic.

At a leading logistics company, managers looked across the fleet to weigh drivers' stops against variables such as timed deliveries and fuel usage. The application of spatial analytics helped prescribe routes that may look counterintuitive to the driver but create measurable benefits for the company and its customers.

A number of algorithms were at play for the company's analysts to identify the best routes between locations and to weigh decisions against real-time traffic, turn restrictions, barriers, and costs.

Essentially, the analysts looked at their service area as a cost surface and used cost-distance analysis to compare route options. They created an origin-destination cost matrix to sequence stops, then optimized the order of stops for speed, cost, or fuel efficiency.

The sequence and routes are continually updated as barriers or delays are encountered. As routes are recalibrated, drivers are constantly made aware of the changes through smart maps on their mobile devices.



Here's how spatial analysis answers the logistics company's critical questions.

- **Path or flow along a network: What is the best route between points?**

  The objective of creating optimal paths is to connect starting points and destinations by greatest speed, lowest cost, or any other metrics. A least-cost path analysis—taking a set of starting points, a set of destinations, and information about the landscape and any challenges in between—finds the most efficient way to travel. Unlike a simple distance calculation, spatial analyses consider more factors like terrain, weather, or vehicle capacity. Traveling uphill or into the wind has an impact, for example, because of gravity, effort, and fuel efficiency.

- **Determining optimal routes using travel times, traffic, and closest drops: What are the next three top priority deliveries?**

  Movements from point A to point B are constrained by drivetimes, a vehicle's characteristics including height and width, and road factors such as one-way streets or left turns into oncoming traffic. Travel times and traffic also impact the sequence of stops and dictate the best times to deliver to certain locations. Using spatial methods like route or network analyses, either run individually or in sequence, companies can prioritize deliveries and design optimal routes.

- **Determining overlapping relationships in space and time: When and where will a storm impact long-distance haulers along a highway route?**

  Planning for weather-related route disruptions requires locating the intersection point of two moving objects (a vehicle and a storm). This kind of spatial analysis is called *spatiotemporal or time-series forecasting*, and it uses queries to compare the objects' locations and speeds, predict their positions at different times, and identify where and when they will both be in the same place.

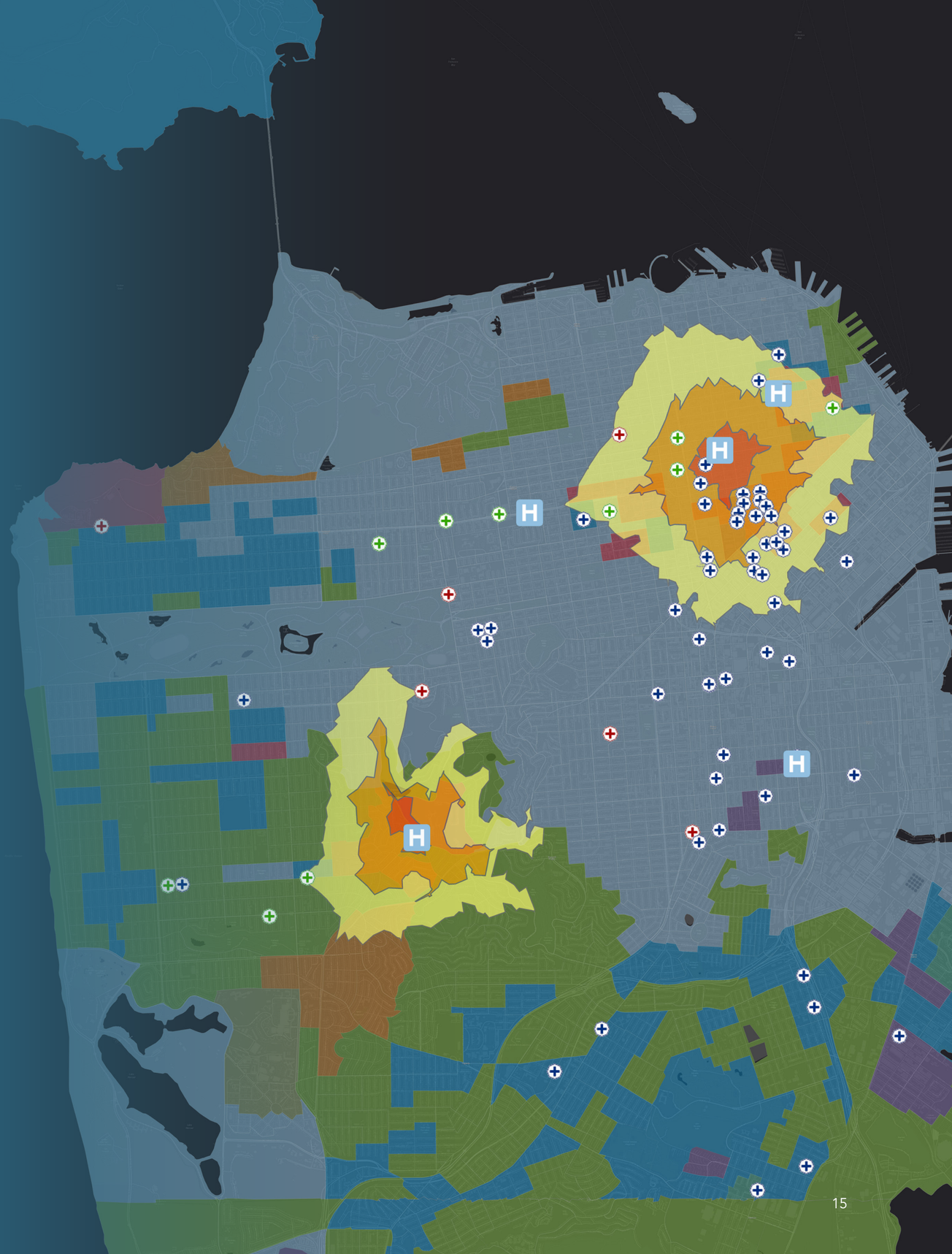
Highlighting Health Priorities: Tackling Complex Challenges

So much of a person's health is a by-product of *where* they grow up, *where* they live, and *where* they work. Nebulous data, when linked by location, can fuse into patterns that may otherwise be overlooked such as prolonged exposure to air pollution or shared water sources or access to clinics, hospitals, or vaccine distribution points.

Those patterns, when looked at through social equity analysis and spatial statistics, can help analysts in the health field determine where their organizations should make investments or prioritize treatments.

Take, for example, the locations of dialysis clinics relative to rural patients. A table with data about kidney disease prevalence is nothing more than a list before being connected to the census tracts where patients in need reside. From there, one can determine travel times to the nearest dialysis centers and visualize care deserts. By seeing where everything is, health-care service providers can prioritize where to make investments in new clinics.

That type of analysis can be done entirely and transparently on a web browser in Esri's Map Viewer, which has the capability to replicate the results through recorded actions.



HEALTH USE CASE

Researchers Unlock Opioid Overdose Patterns Using Spatial Analysis

Opioid overdose and the disease of addiction continue to be a tragedy for the US health system and the public. There were 80,816 fatal opioid overdoses in 2021, nearly 11,000 more than there had been in 2020.

Now, there are generic and over-the-counter versions of the life-saving drug naloxone that can reverse overdoses. The next steps include ensuring doses are available nearby during critical moments and opening health-care clinics in opportune locations. For both, it's important for health services agencies to understand where overdoses are occurring—a trend that can be visualized through hot spot analysis.

One health services researcher discovered that visual analysis and location analytics have an edge over traditional models when describing problems and pinpointing where efforts should be made. They've taken a map-everything approach and used data to detect changes over time to help understand the progression of drugs, the movement of dealers, and the disease.

Daily, they map where overdose incidents occur, using all available data to identify priority zones to target.

By creating a statistical model with county-level data on social, health, and economic determinants, the researcher is revealing relationships between geographic factors and the opioid mortality rate. In this way, they are pinpointing risk indicators and helping health-care services proactively provide care where it's needed most.

Here's how spatial analysis answers the health-care services provider's critical questions.

Attraction and decay: How will a clinic's size and location attract or divert customers?
Gravity models can help determine ideal travel distances between would-be clinic users and new clinic locations based on need, demand, and other nearby options. First, identify factors such as the populations at each proposed location and the distance between it and the population center. In this case, where drugs are sold and consumed are important considerations. The attractiveness of a particular location tends to decrease, or decay, as distance grows larger. Calculating the attractiveness and considering nearby competition help determine where clinics will be most needed and accessible.

Seeing spatial pattern changes over time: Are more overdoses happening in certain places in my city?
A hot spot analysis of overdoses in a particular location and how those hot spots have grown over time can guide decision-making about interventions and outreach efforts. The locations, dates, and times of overdose incidents can create a point layer and allow focus on a region of interest. It's important to determine the expected number of incidents for each census tract, ZIP code, or other area type to detect outliers where there's a higher-than-usual incidence per population size. Pattern detection tools applied iteratively across time identify changes in both time and space.

Seeing significant hot spots: Where should we target our efforts?
Hot spot analysis can quantify statistically significant data values and map where clusters exist—ultimately pinpointing exactly where action should be directed. First, the analyst must be confident that the patterns are significant. Often results are unusual or values extreme, like a high number of overdoses per capita or a long drive time from a ZIP code to a clinic. Finding outliers is best achieved using spatial statistics such as cluster or outlier analysis and exploratory spatial analysis.

Reducing Asset Risk: Maintaining an Accurate Inventory and Coordinating Demand

With increasing risks from climate and related shifts to clean energy, asset managers are dealing with profound changes. Spatial analytics provides a new window on performance and risks to take on these challenges.

Asset managers must balance risks while maximizing performance and reducing operational costs. With spatial analysis, they can see the locations and conditions of fixed and moving assets in real time and predict issues before they turn into disruptions.

Real-time tracking apps record details about every interaction such as inspections, maintenance, inventories, and acquisitions or divestments. These tools enable the collection and compilation of more details on a smart map, enhancing safety and security while improving communication and collaboration.

Reliable and accessible data improves the coordination of every individual part of an organization. Incremental improvements lead to enhanced workforce performance and operational efficiency.

Spatial analytics empowers asset managers with awareness and agility to reduce risk, increase efficiency, and make the most of changing conditions.

COMMERCIAL REAL ESTATE USE CASE

Using Geospatial Technology and Analytics to Unlock Hidden Value

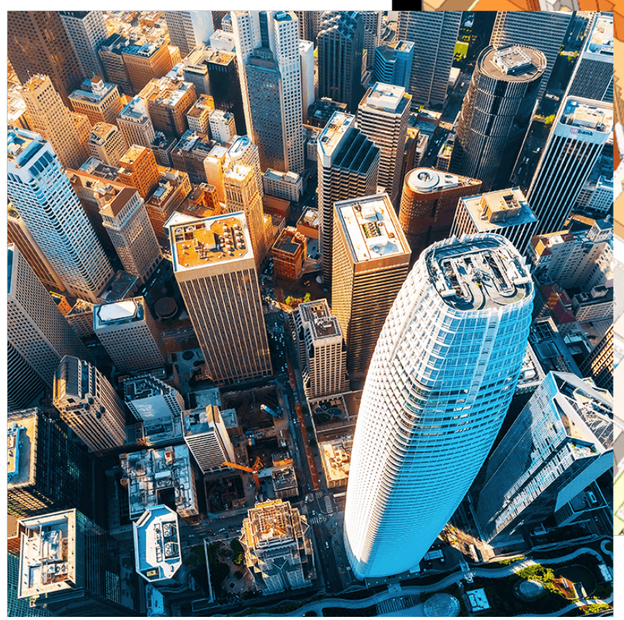
With so many employers embracing hybrid work, there's a growing amount of empty office space in corporate real estate portfolios. Getting a handle on how much space is needed relative to in-person and remote employees involves spatial calculations and a new level of office-use tracking.

Executives at one multinational company needed to keep track of thousands of properties across multiple continents. By applying sophisticated spatial analytics, they gained clarity.

Knowing how the company's buildings and the space within buildings are utilized informs future use patterns. The core tenet of space management is maintaining a space inventory: how much square footage and real estate is available and how many individuals must occupy the space?

The company's real estate portfolio managers can also overlay information about a location's zoning, housing, retail environment, schools, and employment trends. That includes mapping details such as expansion plans for a local transportation network, forecasts for employment growth, information about the pace of business openings, patterns of recent development, and approved development plans.

When viewed on smart maps, those factors provide important clues to a location's growth trajectory. Real estate planners can then use that location intelligence to paint a clear picture of supply and demand, guiding such decisions as the growing trend of turning office space into housing.



Here's how spatial analysis answers the multinational company's critical questions.

Temporal analysis to see trends: How has office space demand changed?
Locations, properties, and relationships change over time. A time series of data for an area or location reveals trends, like shifts in property values. Analysts can compare these trends to possible influencing factors, such as population growth, real estate inventory, or crime rates. After analysis, animating space-time clusters or visualizing change in 3D reflects progression intuitively.

Determining and summarizing what is within an area: How much square footage do we have near our employees?
Spatial aggregation lets you count and summarize data over geographic areas. It might involve simple calculations, such as how many counties are in a particular state. Or it could involve overlaying areas with other data, such as how many cities are within each county. To fully characterize an area, two or more layers can be stacked for analysis of the number of features present. Then, calculations like minimum, maximum, or mean can be applied; feature intersections determined; and unions where an area contains multiple features of interest identified.

Allocation of resources to geographic areas: How should we draw territories now with reallocated staff and changing opportunities?
Location allocation analysis finds the best location for a facility to serve nearby demand. It starts with identifying demand points for a facility, then determines where to locate the facility in relation to those demand points. The ideal location may cover the most demand, minimize costs to reach the demand, or maximize market share. Additionally, territory design tools allow analysts to create, balance, and edit sales regions, service areas, or franchise zones after a facility location has been determined.

Taking Climate Action: Forecast Scenarios for Resource and Risk Management

More frequent and intense natural hazards, such as wildfires, extreme heat, drought, storms, and sea level rise have emergency managers, city planners, and company executives working to protect people and assets. Spatial analytics, including simulations, helps analysts consider damages from in-the-moment crises and factor forecasts into planning for threats.

Emergency managers need to find the intersection of disasters, people, and infrastructure so they can allocate resources when responding to incidents. But with so many data variables in play—like storm models, demographics, and drone imagery—analyses become complex quickly.

GeoAI helps rapidly identify where patterns and connections emerge in seemingly disparate data. The resultant location intelligence guides response plans that safely direct resources where they're needed most.

Once the information is collected and managed, predictive analyses can help leaders mitigate, adapt, and become more resilient before disaster strikes again. Spatial statistics and GeoAI help weigh the effects of different mitigation strategies and monitor changes so decision-makers can adjust plans.

FIRST RESPONDER USE CASE

Predictive Analytics to Fight Ferocious Fires

Wildfire in the western US has continued to break records in acres scorched, structures damaged or destroyed, and people displaced and harmed.

One of the largest state firefighting agencies in the US has applied new tools to improve situational awareness with inputs from sensors, drones, and fellow emergency responders. This smart map has proven to be a game-changer in combating more intense fires. It enables crews to prioritize firefighter and asset allocation, such as bulldozers to cut fire lines or helicopters to drop water.

With spatial analytics, firefighters apply the knowledge gleaned during operations such as removing hazards, planting new trees, rerouting electrical lines and roads, and rebuilding structures. Knowing where things are intact and where they are damaged and analyzing what must be protected or repaired first involves spatial analysis.

Graph Analytics Links Spatial and Nonspatial Objects

Graph analytics is a powerful tool for analyzing complex networks. It can be used to determine important nodes in a network, see what attributes connect seemingly disconnected entities, and identify new clusters of related data points.

When used with spatial data and location intelligence, graph analytics can show where *and* why information is related. For example, retail analysts can use spatial analytics to identify best-selling products or services within a geographic area, then apply graph analytics to link top performers to nonspatial characteristics like price, product category, or paired purchases.

Similar methods can show analysts in manufacturing how a single event could impact multiple nodes in a supply chain or inform analysts in energy how customer type relates to consumption. Pairing these graph analyses with spatial information and map-based visualizations gives decision-makers precise insights about where action will have the most impact.

Ensuring Food Security: Predictive Analytics to Safeguard Lives and Livelihoods

Farmers require regular advisories about their crops and fields to stay on top of constantly changing conditions. This includes daily updates on weather, pests, and the vigor of plants to adjust to irrigation, pesticides, and fertilizer.

Whether borne from sensors, satellites, or surveys, all agriculture data needs to be analyzed spatially to show where to focus efforts. Taken a step further, the information can add crucial context in the form of location-aware farmland digital twins. All inputs are aggregated in a digital representation to model outcomes of management practices and events such as droughts or storms.

In the digital twin, farmers can also see the results of preventive measures, such as spraying, or determine the combination of conditions that led to high or low yields. Data distilled to the hyperlocal level guides resource allocation and operational efficiency for farms of all sizes.

It's a new agricultural revolution—one that aims to fuel prosperity while maintaining environmental sustainability.

AGRICULTURE USE CASE

Improving Crop Choices to Boost Income and Environmental Outcomes

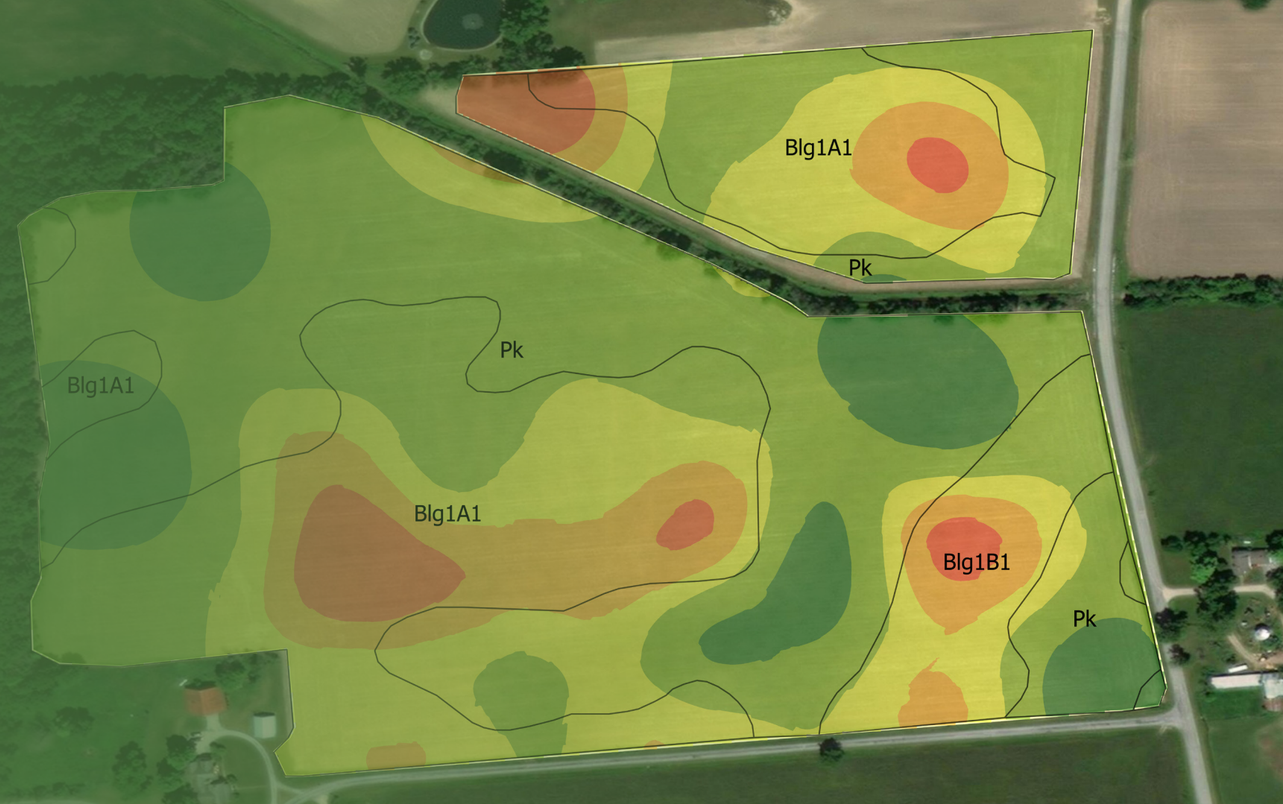
National and regional governments in India have long used satellite imagery and smart maps to track crops. What has been missing, until now, were spatial analytic tools for the individual farmer who has a small landholding.

Data and on-the-fly analysis are now delivered to farmers via a GIS app on their phones, providing customized advice. In addition to forecasts and condition assessments, spatial analysis suggests specific steps the farmer can take based on soil types, market movements, and price analytics.

The app puts the farmer at the center of the analytics by conducting a 360-degree evaluation of the farmer's land, soil, and water conditions. It also considers each farmer's need for a sustained income. It factors in social and family characteristics as well as current and aspirational income. It also considers noncrop activities such as poultry farming, animal husbandry, beekeeping, and farm labor.

Using spatial and nonspatial datasets, the app conducts spatial analysis to assess direct and indirect variables. From there, farmers receive straightforward, personalized messaging that helps boost operations.

Here's how spatial analysis answers the agriculture industry's critical questions.



Determining what is nearby or coincident: What are the environmental conditions around the farm?

Spatial analysis detects areas vulnerable to particular risks. For farmers, this might be identifying fields susceptible to environmental problems, such as erosion, to inform mitigation steps. This is possible by overlaying different layers of data on a map to consider contributing factors such as slope, vegetation cover, soil type, flood risk, and water cycles. The complete, multilayered picture supports plans for mitigation and damage control as well as sustainable operations. For example, farmers can see where to plant trees to minimize erosion and where to upgrade irrigation systems for water efficiency.

Suitability analysis: What is the best crop to plant based on my soil type?

Farmers can use spatial analysis to identify areas of a farm best suited for certain crops or livestock. Suitability analysis involves collecting and mapping data about a geographic area and locating optimal conditions. For farmers, soil drainage, sunlight, and rainfall could be considerations. This data can be layered to show where to plant sun-hardy, drought-resistant crops versus where to plant those that need more water. Suitability analysis can improve outcomes and reduce the risk of failed investments.

Finding factors that explain observed spatial patterns and making predictions: What factors contributed most to enhanced crop yields?

To understand the factors contributing to an observed pattern, it's often necessary to explore a number of variables. The significance of each factor—soil quality, climate, and agricultural practices—must be weighed. Geographically weighted regression can help determine the relationship between dependent and independent variables that vary by location. When crop yield is the dependent variable, the independent variables include weather, soil quality, fertilizer, and pesticide application. A spatial model shows the relative importance of each factor on a map to explain changes in crop yield at each location. Armed with this insight, a farmer can replicate what worked and change what didn't.

Score Different Site Options in Suitability Analysis

Suitability analysis is a process for identifying the best sites for a particular use. It involves evaluating sites according to a set of weighted criteria, then assigning a suitability score to each. Consider these examples:

- A company is scouting new locations for a manufacturing plant. Suitability analysis identifies sites with necessary infrastructure such as roads, water, and power.
- A city needs a new location for a park. Suitability analysis identifies sites with necessary space, access to public transportation, and proximity to schools.
- A government agency is looking for a new location for a landfill. Suitability analysis identifies sites that are geologically stable and have minimal environmental impact.
- A farmer has a new seed and wants to determine the best field to plant it. Suitability analysis identifies fields with the proper soil type and nutrient levels.

No matter the use case, the criteria involved in suitability analysis will be spatial—specific to the location being evaluated. This makes spatial analysis key for not only calculating suitability scores but also visualizing the results. Ultimately, seeing the scores displayed on a map makes it easy to locate the best sites.

Esri Capabilities

Esri's analytics provides a team or an entire organization with all the capabilities they need.

Real-time tools allow users to analyze and display data from sensors, devices, and social media feeds. Analysts can find hidden patterns and trends and gain location intelligence from massive datasets. The ability to see movement as it's occurring provides situational awareness to guide critical, time-sensitive decisions. Seeing moving assets on a shared map enables new levels of collaborative coordination.

Big data analytics powered by distributed cloud computing transforms massive spatial data into manageable information. The computing power available in the cloud allows for on-the-fly map-based representations that animate the movement of data across space and time. Companies can analyze large or complex datasets to reveal patterns, find clusters and hot spots of activity, see relationships among datasets, and predict events.

Knowledge graphs integrate graph and spatial analytics to support data discovery, looking at the dimensions of betweenness and closeness. Graphs add the ability to conduct link analysis to interrogate entities and discover important connections between people and places. This approach can also be used to analyze events or movements. Link analysis and visualizations with link charts are key to understanding network structures and functions and to the optimization, influence, or disruption of a network.

GeoAI accelerates spatial problem-solving by combining spatial analysis, raster analysis, and AI. This combination in one system can handle massive datasets, run analyses rapidly, and power more accurate predictive models. With GeoAI, companies turn data into storytelling to show what's happening—from input to outcomes—in relation to applied strategies.

To learn more about our analytics capabilities, visit:
esri.com/en-us/cp/location-analytics-for-data-scientists-analysts.

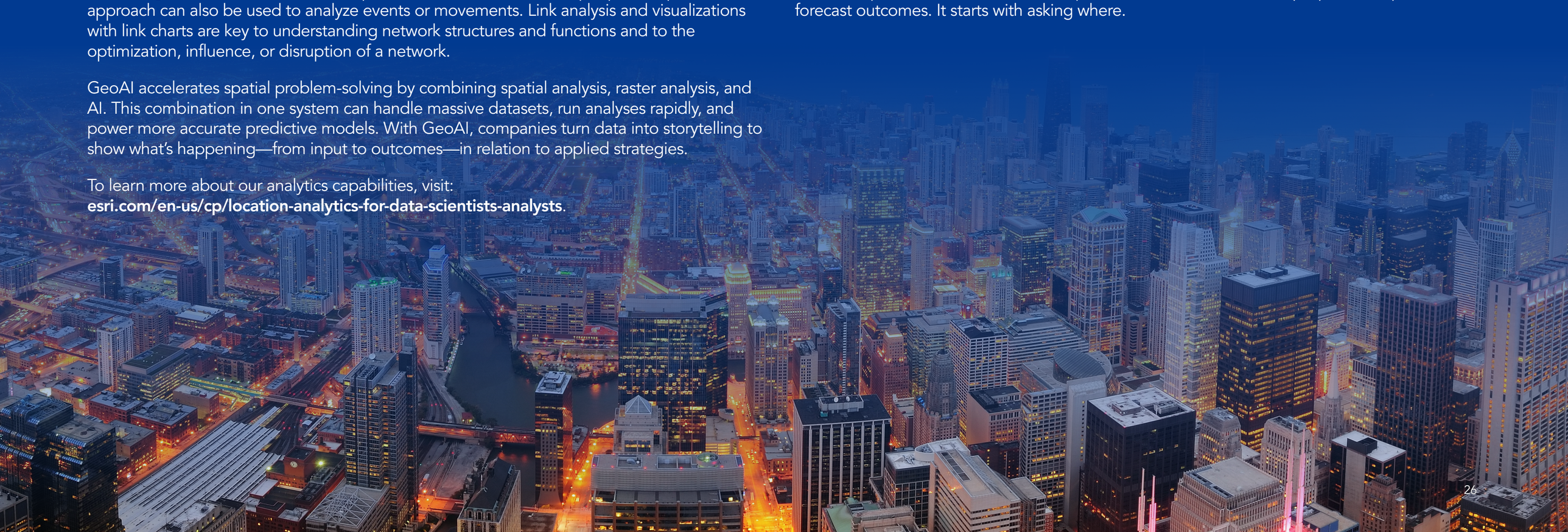
Conclusion

Spatial analytics combines big data with real-time and IoT streams, imagery, and more—making sense of it all by linking information to place and time. Across an enterprise, it supports the analysts and data scientists as much as it supports the executives and operational managers.

With ArcGIS, spatial analysis can be seamlessly added to existing workflows. Results can be shared widely among audiences of all sizes via compelling maps that tell stories. After all, what good is powerful analysis if it can't be explained or easily accessed by those making key decisions?

ArcGIS is an end-to-end solution for analysts—from data management to analysis and visualization—that can be integrated with traditional analytics platforms to bring cutting-edge spatial capabilities.

There is no end to the complex challenges facing businesses, but there are increasingly better tools to simplify and help solve them. Innovative techniques that center volumes of data around a specific location can uncover patterns and reveal relationships, predict impacts, and forecast outcomes. It starts with asking where.



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