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# COORDINATES FOR CHANGE: HOW GIS TECHNOLOGY AND GEOSPATIAL ANALYTICS CAN IMPROVE CITY SERVICES

**An innovative technology harnesses data to reduce costs, improve services, and create a better community for citizens.**

**We're familiar with using maps** to figure out where to go, or how to get from point A to point B. But now we can also use maps to figure out where and when burglaries are most likely to occur in a particular city, the parts of a country most in need of pre-natal health-care clinics, and where a parking spot just became available in a congested neighborhood. The rapid retrieval and presentation of such highly specific, extremely valuable information is possible because of one innovative technology: geographic-information systems (GIS).[1]

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[1] Geographic-information systems include the hardware, software, data, management, and analysis of geographically referenced data. The analyses based on GIS data are referred to as geospatial analytics.

GIS technology allows users to integrate and analyze large, disparate data sets that involve geospatial information—in other words, location data—and nongeospatial information like population density or customer preferences. Through GIS, users can quickly detect patterns and trends that might otherwise be overlooked—a perspective that helps them develop innovative solutions to long-standing problems.

While GIS has been in existence since geographic data met computers in the 1960s, the technology is constantly evolving. The last few years alone have seen particularly dramatic advances related to several trends:

- a sharp rise in the amount of geospatial information available through smartphones, credit cards, social media, global-positioning-system (GPS) devices, Google, and other sources
- an increase in the accuracy of data used to pinpoint locations
- an increased sophistication in the methods used to analyze geospatial information, which is partly enabled by the greater standardization of data and databases
- advances in hardware, such as improvements in GPS receivers and rangefinder devices
- maturation of open-source software, to make data more accessible to a broader group of people

These changes have produced a quiet revolution in which geospatial data are increasingly applied in new and innovative ways. (They have also heightened concerns about data privacy.) Private companies, recognizing that GIS can help improve profitability and optimize many aspects of their business, have welcomed the advances, and invested heavily in GIS initiatives. Some governments, both local and national, have also launched new geospatial projects that fully exploit the recent advances in data and technology. Many, however, have yet to make full use of GIS capabilities, thereby potentially missing opportunities to reduce costs, improve services, and create a better community for their citizens.

We undertook extensive research of the use of GIS and geospatial analytics at the city level to determine how urban areas could benefit from greater use of innovative geospatial technologies.[2] The first section of this paper describes our findings on the most relevant applications of GIS in city settings, focusing on those related to information dissemination, planning and analysis, and service delivery. The second section discusses three key enablers that help GIS initiatives succeed, including strategies to increase information sharing among departments, partnerships with private companies or academia, and an emphasis on citizen cocreation. Throughout the document, we present case studies based on our research to illustrate best practices and potential results.

## 'Location, location, location': How GIS technology and geospatial analytics improve decision making

Dry definitions of GIS technology and geospatial analytics do not convey their full power. For that, we need to look at real examples. Some of the best come from the private sector, where many companies have readily adopted geospatial analytics. UPS, for instance, famously used geospatial analytics to direct its drivers to more efficient routes that favored right turns over left. Since many states in the United States allow right turns on red, this change reduced idling time and cut fuel costs by $3 million annually. Other companies, such as Starbucks, now offer mobile applications that help consumers locate the nearest store based on their phone's GPS data. And ComfortDelGro, Singapore's largest taxi company, has an app that identifies

[2] This report is based on research conducted in over 30 cities, as well as interviews with geographic-information-systems experts from the private sector and academia. When examining cities, we conducted our most in-depth research on those that were using geospatial analytics in the most innovative and sophisticated ways. Our research allowed us to create more than 150 case studies about the use of geospatial analytics in urban areas.

the location of people who want rides using data from their smartphones.

Like their private-sector counterparts, some governments have started to incorporate sophisticated geospatial analyses into decision-making processes. Experience shows that three areas can reap significant benefits from GIS and geospatial analyses: information dissemination, urban planning, and service delivery. Across each of these areas, GIS technology and geospatial analytics can increase speed, accuracy, and cost effectiveness related to a wide range of government priorities, including those related to crime prevention, emergency management, disaster recovery, social services, health care, transportation, urban planning, environmental initiatives, and facility planning and management.

### *Information dissemination*

People often complain that it is difficult to learn about available government programs, regulations, and services, in both developing and developed countries. The problem is usually not that governments lack data on these topics; it's that the information is either inaccessible to the general public or too complex to allow for rapid interpretation.

GIS technology, with its mapping capability, can help the public visualize information about their communities in a more rapid, interactive way. Hong Kong, for instance, has used GIS and geospatial analytics to create an online street map that shows where historical sites, cycling tracks, and other public facilities are located. Users can easily navigate through the map with a cursor and click on a location to see more detailed information. Cities have also released GIS technology and geospatial analytics to disseminate more complex information, including data that citizens would have difficulty finding through any other source. In San Francisco, the SFpark initiative collects real-time information about available parking spaces using sensors embedded in lots and ports the information to a public website. The system also adjusts prices dynamically—charging less in areas with many open parking spaces—in response to shifts in demand. Among other advantages, SFpark reduces traffic congestion by decreasing the number of drivers circling and double parking. The public, in turn, benefits by having more certainty about available spaces.

### *Planning and analysis*

Just as geospatial information helps companies find the best locations for their stores, bank branches, or other businesses, it also helps governments determine where to place publicly funded facilities, such as hospitals, clinics, sporting arenas, subway lines, police stations, and community centers. In Uji City, Japan, for instance, planners used GIS technology and geospatial analytics to reduce the time and effort required to determine where new child-care centers should be located. Through their analyses, they could rapidly identify areas with the highest density of young children and then visualize the information on a map.

Beyond facility placement, GIS technology and geospatial analytics can also help with a number of other planning decisions. For instance, Boston has created a GIS map of renewable-energy sources, such as solar and wind systems, to guide investment decisions, track clean-energy progress, and meet the mayor's goal to reduce greenhouse-gas emissions by 25 percent by 2020. City planners designed the map to show the location of the energy source and details about each site, such as the name of the installer and the kilowatt rating. As another example, the National Library Board in Singapore uses geospatial informa tion to analyze public-library visitorship and book-loan transaction trends. By geocoding millions of transaction records, the board can identify hotspots of library usage, such as the most popular branches, and develop strategies for targeted outreach and optimizing book collections. New York City is also very active in using GIS technology to improve the lives of its residents. For example:

- Analysts in the city's Food Retail Expansion to Support Health (FRESH) program mapped health issues such as the prevalence of diabetes and obesity. The program correlated outcomes to grocery-store catchment areas, discovering that a lack of quality stores was correlated with poor health. Planners integrated this information into their decision-making process to identify areas of high need and change zoning for grocery stores—a move that could decrease residents' dependence on fast food or other unhealthy alternatives. (Note: some studies have not shown a correlation between improved access to grocery stores and health outcomes.)

- Planners in New York City use the Hazards US tool, developed by the Army Corps of Engineers and the Federal Emergency Management Agency, to identify geographic

An ambulance in the suburbs of Chicago is tracked in real time with CompassCom technology, which integrates GIS and GPS to track vehicles for businesses and municipalities.

Exhibit 1

## New York City uses the Hazards US (HAZUS) tool to identify at-risk geographic locations and buildings and estimate potential flood damage.

**FEMA and Army Corps of Engineers developed HAZUS, which is a model to estimate losses from natural disasters**

**1 Identify which geographic areas and buildings are at risk**

The city is divided into grids, which are categorized by 35–40 different building types

Flood analyses determine which areas are at risk of flooding and how high the water could be to identify buildings at risk

**2 Develop damage estimates for buildings**

For each building type, HAZUS has "damage curves,"[1] ie, the expected damage to building based on depth of flooding and time the building is inundated

**3 HAZUS can estimate the cost of the storm, given a potential flood:**

- Repair costs for buildings
- Estimates of quantity and type of debris in each grid

The analysis can be done for different mitigation scenarios (eg, flood proofing, levies) to quantify avoided costs and identify the most appropriate countermeasure

[1]These curves were specially customized to New York City's building stock.

Source: Interviews with New York's Office of Long-term Planning and Sustainability; interviews with New York's Office of Emergency Management; Federal Emergency Management Agency

areas and buildings at risk of flooding, as well as the potential economic loss from such damage. They incorporate this information into investment decisions on climate-change initiatives (Exhibit 1).

### *Service delivery*

Governments control a broad array of decisions related to education, health-care provision, and public safety. Yet they can struggle to provide high-quality services to all segments of society, especially when large or demographically diverse areas are involved. When governments fail, the consequences can be severe, ranging from lagging test scores among schoolchildren to crime surges in neighborhoods that suffer from inadequate police coverage.

Government leaders and public sector employees can improve service delivery by using GIS and geospatial analytics to optimize resource deployment. For example, health departments and emergency services could use geospatial analytics to pinpoint the best locations for dispatch facilities or hospitals based on projected ambulance transport time. Governments can also use GIS information to determine which locations are most in need of specific services. In the United Kingdom, for instance, the National Health Service's (NHS's) "New Leaf" program uses GIS to locate areas with a high number of smokers. For instance, it looks at the number of patients with chronic obstructive pulmonary disease or other illnesses commonly related to smoking, as well as areas that have a high number of people who fit the demographic profile associated with smokers. After identifying high-risk areas, the NHS locates smoking-cessation programs there. The NHS has also used GIS to map the prevalence of other health conditions, such as the number of diabetes-related amputations, and used the information in geospatial analyses to determine where it should launch various health initiatives (Exhibit 2).

Governments and citizens can use GIS technology and geospatial analyses to improve service delivery. In Boston, citizens can report municipal problems, such as vandalized or damaged public property, through its Citizens Connect program. Users can identify issues through the program's website or call center, or by using a mobile application. All reports are geotagged, directed to the appropriate agency, and resolved as promptly as possible.

Exhibit 2

## Geographic-information systems and geospatial analyses help the UK National Health Service determine where specific health initiatives should be offered.

**Health-care topics investigated**

- Amputations due to diabetes
- Access to dentists
- Infant-mortality rates
- Rate of healthy-eating habits

▶

**Initiatives supported or informed**

- Immunization drives
- Dental-hygiene drives
- Anti-obesity campaigns
- Diabetes-awareness campaigns
- Free health screenings
- Breast-cancer screenings
- Drug-addiction outreach
- Healthy-eating campaigns
- Liquor-license-renewal lobbying
- Specifying which drugs pharmacies should carry by region
- Family-planning campaigns

Source: National Health Service press releases; National Health Service website

## Are there privacy concerns?

Few people doubt the benefits of GIS technology, but there are increasing concerns about how information on people's behavior, personal characteristics, or history is tracked and revealed. Goverments can mitigate risks and alleviate concerns by aggregating data to a level that prevents individual identification. For example, some city governments now collect cell-phone data to monitor traffic patterns, but protections are in place to ensure anonymity. Telecoms typically assign random ID numbers to each phone number and change them every 24 hours. Since the government is only provided with the anonymized information, it cannot identify the location and travel patterns of specific citizens. The database of location information is also purged after a specified period, and only aggregate or analyzed data are retained.

For instance, when numerous Bostonians complained that bulk-item trash pickup was difficult to arrange, the city responded by sending pickup dates in real time and automating the scheduling process. Many other US cities have since developed or are in the process of developing similar phone centers, often known as 311 services, that allow citizens to report problems.

As another example, Boston's Street Bump app allows citizens to help improve neighborhood streets. As users drive, the app's accelerometer senses bumps that indicate a pothole and records their location. The data are collected and analyzed using algorithms that filter out bumps related to manhole covers and other normal infrastructure. After identifying true potholes, a crew is dispatched to repair them.

For concerns about the ability of GIS technology to track individuals, as well as the ways that city governments are protecting citizens, see sidebar "Are there privacy concerns?"

### GIS in government: What needs to happen

Governments with extensive GIS experience may have sufficient skills and resources needed to implement new initiatives rapidly. Those with less experience may find it helpful to proceed in phases, running pilots and developing detailed business cases before building capabilities at scale. This approach can allow governments to build robust databases and supporting systems, as well as a fully functional GIS team, before beginning large-scale projects.

Governments may have different capability levels and objectives for GIS programs, but they can all benefit from three key enablers:

- sharing information across government
- pursuing partnerships with the private sector and academia
- promoting citizen cocreation

#### *Sharing information across the organization*

Government workers around the world share a common frustration that it is difficult to exchange data with other departments. This obstacle limits the value of GIS analyses, which require multiple agencies to contribute current geospatial and nongeospatial data, including information on demographics, health-care utilization, travel and transport, terrain, building attributes (such as age and height), and three-dimensional images of land, topography, or building layouts.

In many cases, information sharing is difficult because government departments rely on different data sources and computer platforms. Getting all groups to agree on a uniform approach to data collection and management would facilitate progress, but this may not be possible in decentralized systems where agencies operate autonomously. More centralized governments, especially those where one person is in charge of GIS initiatives, are more likely to be successful in adopting a common platform and sources. In San Francisco, which takes a centralized approach to geospatial analytics, the Enterprise GIS Program maintains ownership of commonly used geospatial data and uses this when providing services to city departments and the public. (Importantly, more specialized data are maintained in individual departments.)

If governments do create uniform platforms for information exchange, they should consider instituting safeguards to ensure that data are adequately protected. For instance, data sets could be classified into levels based on sensitivity. The lower layers would be accessible to all or most personnel, with progressive access restrictions for higher layers. With such protections in place, departments might be more willing to share information. For more information on security concerns, see sidebar "Are there security concerns associated with GIS data?"

Governments may also facilitate information exchange—and possibly reduce costs and timelines—by establishing a centralized GIS expert team that oversees joint projects between departments and helps all involved personnel find information more easily. In Boston, a central GIS team worked with multiple agencies to develop the "SnowCop" program to improve street clearing after storms. It allows city managers to make decisions about where to deploy plows in response to geotagged citizen requests, GPS information on the location of plows, and data about the time a street was last cleared. The collaboration was so successful that Boston is now using a similar strategy to address other municipal issues.

In addition to management of multi-agency projects and data retrieval, effective central GIS teams may take the following measures:

- work collaboratively with other staff at government agencies to develop GIS applications and services
- provide geocoding assistance, such as translation of a database with addresses to x–y coordinates for mapping
- create training programs and support in-house staff in developing GIS capabilities
- incorporate GIS technology into existing business processes and suggest additional improvements
- manage issues with GIS systems, such as the transition from legacy programs
- assess an agency's current GIS technology and provide advice on appropriate software programs and GIS trends

> If governments create uniform platforms for information exchange, they should consider safeguards to protect data.

***Pursuing partnerships with the private sector and academia***

Governments, businesses, and academics are all pursuing geospatial initiatives, and there may be some overlap between their efforts. Building partnerships across relevant organizations and sectors can allow different groups to pool their capabilities and resources, thereby reducing redundancy and helping to catalyze better insights.

Some of the most compelling partnership examples come from the health-care sphere. For instance, a research team from the Chinese University of Hong Kong (CUHK) worked with the government to create a geospatial tool that identified areas in the city where the public was at high risk for dengue fever. Based on data from the government's Food and Environmental Hygiene Department, the CUHK researchers determined the number of mosquitoes—the primary means for transmitting dengue fever—found in traps throughout the city. It also tracked temperatures—a key indicator of where dengue-carrying mosquitoes are more active—using data provided by the public Hong Kong Observatory. By combining mosquito count and temperature informa-

## Are there security concerns associated with GIS data?

An investigation by RAND, a United States–based think tank, examined the dangers inherent in releasing geospatial information by looking at 629 US federal data sets to determine what information in them met the following criteria:

**Usefulness.** Could the data be used to identify a target and get location information (such as facility construction details)?

**Uniqueness.** Was the information available through other sources, such as paper maps, in-person visits, agency websites, or data tables?

**Societal benefits and costs.** Did the data provide important public-safety or transportation-access information, such as locations of gas infrastructure or bus stops? Does the value of providing the information to the public outweigh potential negative outcomes?

The RAND analysis found the security risk was low. For instance, fewer than 6 percent of data sets contained information that could be used to identify a target or plan an attack, and fewer than 1 percent were both unique and useful. The researchers also determined that no single data set provided attackers with information that was essential to their plans.

tion, the researchers were able to create an online heat map that showed high-risk areas. Users can see alert levels for the city as a whole or for individual districts. They can also enter their address to receive dengue alerts for selected areas.

In another partnership, the Shanghai municipal government worked with Veolia Water Corporation, a company that manages water and wastewater services, to install and monitor sensors throughout the 3,300-kilometer piping network. Through this collaboration, Shanghai obtained real-time, detailed, geotagged data about water pressure and quality. The city used this information to identify precise locations of network issues, such as leaks. The real-time data dramatically improved response time for repair crews, which translated into less damage to the water infrastructure, lower maintenance costs, and reduced disruption of services. The information also helped crews see which pipes were at risk for rupture and group them accordingly, which helped set priorities for preventive maintenance.

In some cases, cities have partnered with multiple external groups on GIS initiatives. For instance, the Wellbeing Toronto website provides a color-coded online map that residents can use to visualize how neighborhoods rank on various indexes, including health care, housing, culture, transportation, and education. They can also combine several domains to create a composite well-being index. When developing Wellbeing Toronto, the city obtained data from numerous external groups, including a local hospital, York University, and the Wellesley Institute, a Toronto-based nonprofit organization.

The most successful partnerships typically involve two or more parties that are equally invested in the project. Rather than simply exchanging data, they are willing to meet, share ideas, and talk openly about questions to arrive at solutions. It also helps if both parties have compatible computer systems, or at least use the same data sets, since they will otherwise have difficulty sharing information (similar to the challenge that government departments face when trying to integrate incompatible systems).

As part of the partnership, both parties should reach an agreement about who "owns" the data and any resulting tools or insights. This understanding can help avoid potential legal battles over intellectual-property rights. While both parties might have an equal claim to the data, other partnerships might involve more one-sided agreements in which a single group has the right to use the findings.

### *Promoting citizen cocreation*

It is often time-consuming, expensive, and tedious to compile the extensive data sets needed for geospatial analysis. But governments may be able to reduce some of the complications by promoting citizen involvement in various ways. For instance, as in Boston Connect, the government could call on citizens to report problems in their neighborhoods, such as damaged public property. Although governments cannot mandate participation, they may find that public interest is high and that people want to be part of the solution, especially for problems that concern their own neighborhoods. Governments could also encourage citizen participation by offering themed competitions or "hackathons" in which computer programmers, professional or amateur, develop geospatial applications based on public data. For instance, the US Department of Health and Human Services holds meetings in which it shows stores of data to leading health-care and technology experts. The agency then challenges them to develop apps based on the information and present them at "Health Datapaloozas."[3]

[3] For more information, see "Unleashing government's 'innovation mojo': An interview with the US chief technology officer," mckinsey.com, June 2012.

## A central database of public reports can promote efficiency by reducing response times and making it easier to analyze data.

If governments decide to collect information from the public, it might be helpful to create a central database of all reports and requests, which will provide officials with an integrated view of the issues that matter to constituents. A central database can also promote efficiency by reducing response times and making it easier to analyze data (such as the number and type of requests by location). New York City, for example, has a GIS-enabled service, NYC 311, which serves as a one-stop service for municipal issues. To create this department, the city consolidated call centers from 14 agencies and also began online and mobile-reporting services. NYC 311 now receives over 60,000 calls daily. Benefits of the centralized group include the following:

**Increased convenience.** Citizens only need to know one phone number or website to receive help from all city agencies.

**Greater efficiency.** NYC 311 has set rules for routing calls, which helps ensure that they go to the right agency. One-stop reporting also eliminates the time-consuming step of having one agency to contact another if it receives a request outside of its purview.

**Better performance management.** All service requests are tracked centrally and top managers receive frequent progress reports. If there are problems—for instance, specific requests that take a long time to resolve—managers can review work processes to identify areas for improvement.

If governments do encourage citizen cocreation, they should ensure that safeguards are in place to filter “noise” from the system, such as prank calls or frivolous complaints. For instance, callers who make nuisance calls could be fined or even charged with criminal acts. Some cities have also had success by requiring users to create a login or password to monitor their activity.

If many citizens begin contributing information, governments may be overwhelmed with data or requests for service. To ensure the most important problems receive the most rapid attention, officials can create procedures for prioritizing reports, similar to how emergency phone calls are ranked.

One major hurdle to citizen cocreation programs is a lack of public awareness. If only a few people are making complaints or sharing information, the data may not accurately reflect the concerns of the population as a whole. Some cities, including Boston, New York, and Seoul, advertise their geospatial services to increase awareness. Others publicize helpful civic tools that were created based on city data, which also increases public awareness. For instance, the government of Singapore arranged to have exhibits displayed at the Singapore Art Museum related to real-time geospatial data. The exhibits visualized how the time needed to get a taxi increased during rain, changes in air temperature related to air-conditioner use, shifts in traffic-flow patterns throughout the day, and other interesting aspects of life in the city.

As with partnerships, cities must carefully consider intellectual-property issues during citizen cocreation projects. If the city owns the data but the work was done by a private citizen—for instance, a computer program based on city data—there could be disagreements over which party should profit.

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City governments are increasingly open to GIS initiatives, partly because of the impact they are observing in the private sector, but few have embraced their full potential. To achieve the potential, we see a major role for geospatial analytics in three areas: information dissemination, urban planning, and service delivery. Governments can strengthen their performance by ensuring that key enablers are in place before launching extensive GIS programs. As GIS adoption grows, it could potentially have an even greater impact in the public sphere than the private sector, given the scope and scale of government services. ■

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