Deriving Insight from Data for Smarter Urban Operations

Addressing the "data rich, information poor" nature of today's cities

Catalyst

The world's iconic cites have outlived empires, countries, and civilizations, and are continuously evolving to survive changes wrought by environmental shifts, population growth, technological advances, and a host of other factors. As a result, cities and amalgamations of cities have become the most complex systems of our time. This complexity, combined with ubiquitous sensors in the built environment and a proliferation of communications channels, is creating unprecedented amounts of human intelligence and machine data. Concurrently, the cost to store all this data is falling.

But while cities are collecting more raw data than ever before, they are encountering difficulties in breaking down silos and converting the data into usable, actionable, accurate information – information that can empower transformational leaders by reducing complexity and enabling them to make rapid, fact-based decisions. A major challenge for every mayor, city manager, or agency director is harnessing existing information to transform the way the urban environment is managed. For example, in most cities, ambulances are stationed at a single, central location, even though data often suggests that ambulances parked at specific locations around the city, based on predicted events and historical need would be able to respond to emergencies more quickly. To realize their vast economic, social, and cultural potential, cities clearly need to become smarter.

Ovum view

The reasons behind the "data rich, information poor" nature of today's cities are myriad, including issues with data collection, standalone systems, human capital/analytic know-how, local politics, agency culture, and budget. Although technology is clearly not the solution to all aspects of this
problem, it can serve as the major catalyst. Ovum sees tools surrounding data integration, master data management (MDM), data quality, business intelligence (BI), advanced analytics, and visualization as key to the progression toward smarter municipalities characterized by operational systems that provide rapid insights for more informed, transparent decision-making.

**Key messages**

- Cities have become far too complex and important to be managed without the help of integrated information systems. Like modern airlines, they are guided by pilots that “fly” them, but it would not be possible to fly airlines without the avionics control systems that present constantly updated data and provide context-based situational awareness. In moving toward a comprehensive view of a city's operations, the challenge, then, is to design solutions that address the system’s specific needs and also interconnect with data coming from other systems.

- Achieving intelligent operations means having access to data across multiple sources, with tools to correlate it accurately, analyze it rapidly, and see it visually – anytime and anyplace – to enable fact-based decision-making and make agencies more nimble, transparent, and effective.

- While data collected by cities has increased exponentially during the last few years, it is not all of significant value. City governments must understand the difference between significant and non-significant data in their specific contexts.

- Data silos are the biggest obstacle to more integrated urban operations. Good data management practices and strong leadership can lead break them down.

- Advanced analytics, self-service BI, enterprise performance management (EPM), visualization techniques, and mobile BI can layer on top to deliver intelligent operations.

- Overall, the above five messages are important to help cities improve citizen services, ensure health and safety, and drive economic vitality. The objective is to derive true business value by increasing revenues and reducing operational costs.
DATA-RELATED CHALLENGES IN THE MODERN MUNICIPALITY

Silos are enemy number one

Silos or standalone systems are the basic and most well-established adversary to more integrated operations. They separate data between departments and sometimes even within departments, so that a single view of a city system becomes impossible. The reasons behind them are not always technical; indeed, more often than not they are organizational or political. Most city systems grew up in a relatively haphazard manner, with different regulatory, political, procurement, and technological requirements. IT systems are consistently adopted as specialized solutions in different parts of the organization, without consideration for integration or how they might be utilized both internally and externally in the future. In some cases, there are even forces within departments that want silos to be maintained. But whatever the reasons, silos will become more entrenched the longer they survive, particularly given the volume, velocity, and variety of incoming data, and addressing them will take a mixture of appropriate technology, strategy, political will, and leadership. The silo problem is a universal one, endemic to many different regions and industries.

Data challenges in developing versus developed world cities

Mayors in developing world cities have different data-related challenges from those in the developed world. Cities such as New York City and London, laden with legacy – but functioning – systems, face the need to massively retrofit infrastructure and progressively move up the value curve to become "smarter." Much of the requirement to drive efficiency and improve operations – in addition to improving service levels for citizens and lowering costs – comes from the need to compete more effectively with other cities in the future for human capital, investment, and job growth.

Cities such as Mumbai, Nairobi, Lagos, and Karachi, which are still struggling to provide basic services to large segments of their populations, are unable to handle the volume, velocity, and variety of incoming data, given their reliance on manual processes and their lack of automated records digitization. Infrastructure tends to be more basic, with less instrumentation and therefore less incoming sensor-based data. Land use is often informal and not accurately mapped or zoned, and thriving informal markets make tax collection a problem. Although social media use and network access is rapidly increasing in the cities of developing countries, the overall percentage of their populations represented online is still considerably lower compared with the cities of developed countries, so less human intelligence data is gleaned from the constant monitoring of public conversations on the Web.

However, cities of developing countries are often unburdened by large, legacy technology systems, and often have an expanding tax base due to a rapidly growing middle class. This, combined with the incredible pressures exerted by burgeoning populations and migration, means there is a massive
opportunity for planners and leaders to invest in high-return improvements to city operations, which can result in tangible and near-immediate improvements. Newly constructed cities, which are proliferating, will also have the opportunity to start from scratch. Ovum believes that mayors of cities of developing countries have a historical opportunity to set their jurisdictions on exciting new trajectories, combining improved infrastructure, data-driven governance, and the use of "citizens as sensors" to better inform urban planning and crisis intervention.

The nature of data in an "always-on" society

Urbanization is one of the main drivers of the spread of connectivity through society. The consumerization of IT has followed this driver, and most of humanity is now connected via mobile networks or the Internet. In developed countries, particularly within the Asia-Pacific region, smartphones are heading steadily toward ubiquity, while in developing countries they are rapidly picking up market share. This brave new world is manifesting itself across the globe as conglomerations of always-connected societies, leading to new opportunities, threats, and governance challenges for governments.

Indeed, pleasing the "end user" means something different now compared with five years ago. Citizen-facing services and solutions need to be more consumer-friendly and people-centric. Cities' constituents have generally become accustomed to the ease and speed with which they can access individualized data in their daily lives, to buy books, connect with friends, or reserve a table at a restaurant, for example. They should be provided with the same capabilities when accessing data for community needs, which may be as varied as applying and paying for business or event permits; informing the city about broken street lights, potholes, and graffiti; and looking up transit schedules and transport delays. Data access must be fast, intuitive, and customizable to community needs.

As a result, there is less acceptance of traditional, top-down approaches to policy development and government service delivery, with citizens looking for governments to be more agile and to interact with the community in new ways. In Ovum's view, governments need to see themselves as co-producers, working in partnership with an increasingly empowered digital community.

Open data: a double-edged sword

The cognizance among many city governments that a "two-way" model of governing is desirable, with more co-production and government/citizen interaction, has given the open data movement its momentum. Open data – the switch of data from proprietary or non-reachable to freely usable via machine-readable formats – is a means to increase citizen trust in government, fulfill transparency goals, share information internally between agencies, and provide the basis for co-creation by government and citizens. It can also disrupt how government services are delivered, if apps and better citizen/government interfaces can be created by developers using open APIs. Part of this puzzle will be illustrating that the market holds commercial value for the developer.
As cities develop their thinking around open data and ponder how it will impact city operations, a number of instructive obstacles arise. For example, it would not be fair to post a complaint about a business submitted through a government hotline or another mechanism without knowing if there is merit to the complaint. Automatically rendering incoming public data universally accessible creates many opportunities to "game" the system and the potential for decisions to be based on inaccurate data. Embracing open data therefore requires sophisticated data management and analytical tools that can test for data validity, as well as frank and transparent discussion around privacy issues.

The pressure to collect and utilize more types of data

The types of data that can and must be collected have proliferated, along with pressure to use this data as the basis for better service delivery and decision-making. There are four main types of data sources: factual, mathematical, observational, and emotional, and connecting across multiple data sources is necessary to create a single picture of the city. City leaders must think hard about how each of these sources will be used, and what the positive and negative impacts may be.

On a more granular level, key inputs include: video data from public safety agencies; social media from Twitter and other platforms; the results of citizen collaboration coming from "monitory apps" such as SeeClickFix and Open311 as well as published open data; tracking data; information produced by machine-to-machine (M2M) communications and instrumented infrastructure; and administrative data collected directly from citizens. However, these inputs are not particularly useful without an effective data management, analytical, and/or visualization layer to make sense of the data. We discuss this later in the report.
ADDRESSING COMPLEXITY IN AN URBAN SYSTEM OF SYSTEMS

What do we mean by "systems of systems"?

If we think of a city as an organism, that organism – the system of systems – can be broken down into categorical components. The categories used by IBM's Smarter Cities initiative, which fall into three buckets, can be useful here:

- city planning/management systems (e.g. agency administration)
- infrastructure systems (e.g. transportation)
- human services systems (e.g. social programs).

These systems often overlap and interconnect, so they cannot be considered in isolation; systems addressing the environment, for example, can be both infrastructure-oriented and planning/management-oriented. The challenge, then, is to design solutions that address specific needs in any one category and also interconnect with data coming from other systems, in order to move toward a comprehensive view of a city's operations. These solutions, in turn, can be applied across two primary operating models: improving the efficiency of day-to-day operations and service delivery; and preparing for unexpected incidents or events, with the goal to respond accurately and rapidly and return to control.

Below we describe two systems in which operations can be vastly improved using data-driven insight, and several of IBM's success stories that clearly illustrate these use cases.

Improving water management

Water is an ecosystem's most important asset, and cities should be able to monitor, predict, and respond to issues with quantity, quality, distribution, and disruption, in realtime. This includes everything from anticipating leaks in a water utilities' system using relevant algorithms to calculating the actual cost of producing water in a municipality in order to establish benchmarks.

For example, a recent IBM project entitled "Digital Delta" is using Big Data to transform flood control and the management of the Dutch water system. The initiative will investigate how to integrate and analyze water data from a variety of data sources, including precipitation measurements, water level and water quality monitors, levee sensors, radar data, model predictions, and current and historic maintenance data from sluices, pumping stations, locks, and dams. Much of the Netherlands' population lives in areas prone to flooding, so the country is already one of the best monitored and
therefore data-rich systems in the world; the next step is to design solutions that can convert this data into information useful for decision-making, which is the purpose of IBM's project.¹

IBM has also embarked on a predictive analytics and smart metering project to help remotely monitor consumption and identify water leaks across the Parks, Recreation and Open Spaces Department in Miami-Dade County, Florida. This project is expected to reduce water consumption by 20% and generate savings of up to $1m per year, and these funds can be allocated to parks services for residents.²

Ovum notes that clear return on investment (ROI) studies can be conducted on systems such as these, which often have quite short payback periods. For example, the ROI case study the wastewater management project of South Bend, Indiana, for combined sewer overflow mitigation, calculated a 123% ROI with a payback period of 1.3 years and annual average benefit of more than $326,000.³

**More efficient transportation and transit**

Robust urban transportation networks, such as roadways, airports, ports, buses, railways, and even bike lanes, underpin economic development and profoundly impact the cultural and social fabric of a city. Information created by and relevant to these networks can be used to make transport systems safer, more efficient, better planned, and more sustainable, with a better customer experience overall.

One example of this is the collaboration between IBM and the City of Zhenjiang, China. Zhenjiang is a city of over 3 million people, situated near the intersection of the Yangtze River and the Grand Canal, with over 1,000 public transportation vehicles and over 80 city bus routes. It therefore has a highly complex and rapidly expanding system, with a multitude of inputs that can impact traffic congestion, road capacity, and customer experience. The city is using IBM's Intelligent Operations Center (IOC) and Intelligent Transportation solution to create a central command center, giving the municipality total situational awareness of its transportation network, and initiating a bus scheduling system that uses analytics to manage traffic patterns and optimize routes.⁴ Realtime updates will also be disseminated across the system to commuters, as needed. Harnessing the value of data can not only improve the transport operations of the city, but also stimulate highly desired knock-on effects, such as increased tourism.

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Leadership and innovation in the age of data-driven decision making

The first and most difficult step toward embracing data-driven decision-making and reducing complexity in a system of systems is changing agency culture. Without this, no amount of technology will be useful, which means leadership is the most important success factor. Ovum believes the most transformational leaders inspire their staff through a well-defined vision, lead by example by starting reform in their own office, and take a very visible role in supporting change – be it technology, process, or culture-related. Leaders must find ways to steady their employees through both the discomfort and the opportunities that come with the sustained period of disequilibrium that is inherent in innovation, and shift mindsets from compliance-oriented to service and innovation-oriented. Analytics and performance management technology solutions help decision-makers take their leadership abilities to the next level, by improving collaboration throughout the organization, enabling decisions to be based on up-to-the-minute realities rather than old information in static documents, correlating data to see what information is useful and what is simply background noise, and facilitating mobility.

Good data management is a necessary precursor to smarter operations

Strong leaders need good data management. One of the oldest adages in computing is "garbage in, garbage out," which means that the result of any analysis will only be as good as the data upon which it relies. Proper data ingestion and processing (cleansing, monitoring, and transforming) is critical to ensuring that decisions are built on good data.

However, unless a city plans and implements proper data management processes and technology, connecting data sources across many sectors of a city can be a timely and costly exercise in coordinating infrastructure, processes, and technology.

Cities need to explore three areas in particular for data management initiatives: data integration, data quality, and MDM.

- Data integration is the extract, transform, and load (ETL) process to better handle data movement and the integration of disparate sources of data across several channels in the city.
- Data quality refers to the software that allows cities to standardize and cleanse data, using a variety of rules-driven algorithms that ensure the data is fit for purpose in a given application or process context. Aspects of data quality include accuracy, completeness, consistency, and currency.
- MDM is a combination of tools and process that allows agencies to create a comprehensive and accurate view of each individual citizen, employee, or particular unit of analysis across a plethora of systems. MDM helps agencies to remove duplicates and inaccuracies in data, and allows them to consolidate records to prevent staff or citizens from using different versions of master data in applications and processes.
These initiatives produce cleansed, de-duplicated, and standardized data that agencies or citizens can consume, explore, analyze, or further integrate. Sound data management helps cities run better, as it allows leaders to make decisions based on data that is complete, valid (the right information in the right context), consistent (across datasets), and timely.

Breaking down silos and consolidating data involves not just a technical rethink of how data is stored and shared across different agencies, but also a recognition by urban organizations that data management initiatives are less about IT and more about running a city more effectively. Ovum believes that it is increasingly important that cities recognize sound data management as an operation-critical function, rather than just another IT cost.
EMBRACING ADVANCED ANALYTICS AND VISUALIZATION TO IMPROVE OPERATIONS

Driving insights with the help of advanced analytics and Big Data

Collating and integrating data across silos is just one part of the journey toward more intelligent operations. Once data is collected, cities need the ability to sift through large and complex data sets to find meaningful patterns for both descriptive reasons (what happened) and predictive reasons (what will happen). In particular, it is becoming increasingly important for organizations to analyze data from a gamut of data sources, preferably in real-time, to gain a better understanding of the pulse of the city and to be able to coordinate resources in a timely manner. Advanced analytics solutions allow organizations to move from just "crunching numbers" to being able to analyze and draw insight from structured and unstructured sources, such as video, social media, situational awareness, transactional, and M2M sources, with little to no latency. Much of this is driven by significant advances and the shrinking cost of processing and storing large amounts of data. What would have once cost a substantial sum and taken weeks (if not months) to compute, can now be done in near-realtime at a relatively low cost.

Self-service BI helps all types of users to understand how the city runs

BI provides information workers with insight into the health of an entity, be it a department, a whole organization, or even a city. Since the 1990s, the promise of BI has been to provide tools, such as reports, dashboards, scorecards, and KPIs, that enable a user to quickly access data and get the answers to questions pertaining to specific data set. The reality, however, is that lengthy and complex BI deployment cycles and a heavy reliance on IT have failed to keep pace with the rapidly changing data requests and requirements of BI end users. Traditional approaches to BI deployments have proven to be slow, cumbersome, and expensive. It has also not helped that BI has only been suited for a selected few users that are well-trained and technically savvy.

At the same time, a new generation of end users has become accustomed to the ease and speed with which companies such as Facebook and Google gather and present personalized data in their everyday lives. Consequently, it has now become an expectation for a BI solution to be able to query and interact with data, on an ad-hoc and intuitive basis.

Self-service BI gives great levels of insight to agency users, through intuitive user interfaces and the ability to easily access and visualize multiple sources of data. The front end allows users to create personalized dashboards and data visualizations easily and quickly, via, for example, a drag-and-drop interface. This allows them to see the data they want to see in a simple way. With in-memory technology, this data can be analyzed and presented at high speed. This means end users are less
reliant on IT to provide the data and analysis, which allows more users, technical and non-technical, to get involved in data discovery, data analysis, and the decision-making process.

**Enterprise performance management to make the city run better**

Understanding how the city runs via BI tools is only useful if it allows users to take necessary actions. EPM solutions permit cities to make actionable decisions based on the metrics that a BI solution can surface. EPM helps agency users manage costs, address regulation and risk, and plan ahead. In particular, it helps users assess the performance of disparate business units and compare them to a benchmark, to help with decision-making at strategic, tactical, and operational levels. BI and EPM together should provide a 360-degree view of the city in planning, budgeting, management, deployment, and monitoring. Ideally, the combination of the two helps users push past the compliance mindset that is so common in government, and move up the value curve toward realtime, iterative decision-making. Objectives should fit within the SMART framework (which stands for specific and clear, measurable and verifiable, achievable, relevant, and time-bound).

**A picture is worth more than 1,000 terabytes**

Part of the challenge of getting more agency users involved in the BI and EPM decision-making process is identifying end-user tools that will engage them. Looking at large amounts of complex data in static tables, graphs, and charts is neither intuitive nor productive, and can result in minimal or simplistic analysis that misses patterns and trends. Data visualization tools resonate especially well with so-called "data grazers" in the organization. These are users who like their data aggregated and unified, make fast decisions, dislike searching for information, and are unconcerned with the underlying systems transforming the data – leaving that control to more technical folks.

Perhaps most importantly, advanced data visualizations allow analysts and users to feel more engaged with the data. They allow them to deduce patterns more easily in large and complex data sets, via heat or tree maps, for example. In particular, a data visualization tool turns large amounts of structured data into compelling visualizations at rapid speeds. These visualizations are highly interactive and respond rapidly even as the amount of data held in-memory grows. Interactivity and speed are crucial for widespread adoption of any end-user tool.

**Map out your data**

Location intelligence, the combination of data visualization and geospatial data, is an emerging and interesting area for cities to explore. A location intelligent solution can illustrate data (historic, realtime, or both) geocoded on a map, bringing much-needed context to data analysis and giving organizations better situational awareness. A map can be a better alternative to a bar chart, cross tab, or similar, for many use cases in a city: in water management, for example, users can overlay a picture of leaks that exist throughout a system on a city map, giving an intuitive feel for how long it would take for workers
Maps also allow agency users to intuitively pinpoint areas that need resources, based on geographic attributes such as borough, zip code, or even a specific building.

The emergence of mobile BI for workers on the move

Traditionally, city agencies have been run from central offices, where every worker has had to be physically present to run a report, get access to data, or make a decision. But as the use of mobile devices as everyday work tools increases, this is becoming less common.

A fresh wave of BI products now offers users the ability to access an organization’s data universe anywhere, at any time, on almost any device. For city employees in the field, such as police officers and maintenance workers, the benefits of mobile BI are clear: field workers can access up-to-the-minute and geo-sensitive data on a real-time dashboard, be alerted of deviations in KPIs while traveling, and collaborate with co-workers instantaneously, wherever they are.

However, mobile BI does not only benefit field workers; it can also be an important tool in the office. For many years, the static agency routine has been to bring a report to a meeting, discuss and amend it with co-workers, head back to the desk to make the changes, and generate a new report. Mobile BI makes this process more efficient by taking out a lot of the “back and forth.” Employees can bring interactive reports to meetings on their mobile devices, instantly query and analyze it based on feedback and discussion, and generate new reports without ever leaving the room. When dealing with complex, overlapping city systems that change in real-time, a more efficient way of working with this data is a necessity.
RECOMMENDATIONS

Frameworks can tame complex and amorphous processes

For mayors and agency leaders, frameworks that comprise a staged approach to innovation are often effective guides toward more intelligent operations, as leaders can visualize progress and report successes as they occur. The framework used will differ for each situation – leaders should resist the urge to fit situations into specific frameworks for the sake of ease – but principles and models used in this capacity in the private sector are equally at home in a municipality, and should be embraced by transformational leaders.

For example, Ovum recommends that decision-makers explore STEEP analysis. STEEP refers to the major external components surrounding an agency’s operating environment: social (demographics, lifestyles, religion, education, etc.); technological; economic; ecological (use of natural resources, environmental degradation, etc.); and political/legal. This framework can be applied in times of rapidly changing external stimuli and information overload, and helps leaders know what to concentrate on, what to analyze, and what to forecast around, to understand how operations might change in response. The results of a STEEP analysis can be the reason for taking on agency transformation efforts to use data more effectively.

Unify your data silos

One of the biggest challenges that cities face is dealing with and eliminating information silos. Cities should invest in data integration, MDM, and data quality tools – ideally integrated as part of a single, robust platform. Since data management is a complex IT discipline, cities also need to invest in the necessary in-house skills and expertise to use these tools effectively.

Pursue agility in data management and analytics

Rapid changes in market demands have a great impact on cities and their IT systems, including data management and analytics. System architectures should be flexibly designed for speed and adaptability on both counts. As cities operate in vibrant environments in which data constantly changes, they should aim to capitalize on low-latency processing architectures that allow them to understand the pulse of the city in the present moment.

For self-service enablement, don’t bypass IT

Self-service BI is about DIY, but within regulatory and governmental limits. While some cities might regard it as a way to remove an IT middleman or bottleneck, it is important not to bypass IT completely. For example, BI mashups without IT involvement can create a mess. IT, principally data management professionals, should be involved in the initial set-up of a system, including configuring...
agile connectivity to back-end data sources. IT should occupy a monitoring role for the self-service BI environment.
APPENDIX

Methodology

- Primary research/vendor briefings: ongoing meetings with government technology vendors and IT decision-makers in government agencies.
- Secondary research: industry publications, broker and analyst reports, academic research, and data from public databases.

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