IBM Center for
The Business of Government

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Using Technology Series

Ten Actions to Implement Big Data Initiatives

A Study of 65 Cities

Alfred Tat-Kei Ho
with **Bo McCall**
University of Kansas

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Table of Contents

Foreword

On behalf of the IBM Center for The Business of Government, we are pleased to present this report, *Ten Actions to Implement Big Data Initiatives: A Study of 65 Cities,* by Alfred Tat-Kei Ho, University of Kansas, with Bo McCall, University of Kansas.


Daniel J. Chenok

Professor Ho's report is based on his landmark study of 65 cities to probe their use of Big Data and, specifically, the use of Big Data in local government decision making. In addition, Professor Ho conducted a survey and phone interviews with city officials responsible for Big Data initiatives. Based on his research, the report presents a framework for Big Data initiatives which consists of two major cycles: the data cycle and the decision-making cycle. Each cycle is described in the report.


Ed Nadworny

The trend toward Big Data initiatives is likely to accelerate in future years. In anticipation of the increased use of Big Data, Professor Ho identified factors that are likely to influence its adoption by local governments. He identified three organizational factors that influence adoption: leadership attention, adequate staff capacity, and pursuit of partners. In addition, he identified four organizational strategies that influence adoption: governance structures, team approach, incremental initiatives, and Big Data policies.

Based on his research findings, Professor Ho sets forth 10 recommendations for those responsible for implementing cities' Big Data initiatives—five recommendations are directed to city leaders and five to city executives. A key recommendation is that city leaders should think about a "smart city system," not just data. Another key recommendation is that city executives should develop a multi-year strategic data plan to enhance the effectiveness of Big Data initiatives.

The report builds on the IBM Center's long interest in Big Data. The IBM Center's report *Realizing the Promise of Big Data: Implementing Big Data Projects*, by Kevin C. Desouza, provided an overview of Big Data in government. Another report, *Using Mobile Apps in Government,* by Sukumar Ganapati, examined mobile data, which is also discussed in the Ho report. *A Guide to Making Innovation Offices Work* by Rachel Burstein and Alissa Black discusses how local governments organize their innovation initiatives.

We hope that this report will assist executives at all levels of government in better understanding the challenge of Big Data initiatives and ingredients to successful implementation of these initiatives.

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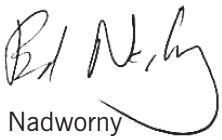

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Introduction

The Rise of the Big Data Era

Big Data has become increasingly popular in recent years. Before the mid-2000s, it was not a major topic, especially when compared with the topic of e-government. However, between January 2010 and March 2016, the volume of Google searches for the term increased almost 16 times, while the search volume for e-government continued to decline. By March 2016, the search volume for e-government was only three percent of the searches for Big Data.

Big Data refers to the use of a massive amount of data to conduct analyses so that the data patterns and relationships can be used for classification, clustering, anomaly detection, prediction, and other needs in decision making (TechAmerica Foundation 2012). Because data collection devices—including scanners, mobile devices, sensors, digital cameras, and radio-frequency identification (RFID) devices—have become easily accessible and widely used in our daily life, digital records of individual and public activities have grown exponentially over time. The internet, especially through broadband and wireless networks, also allows the easy and continuous transmission of machine data. Transmission logs and network status have also become new forms of Big Data (Power 2014). As a result of all these developments, observers of the movement to Big Data suggest that we are already in the zettabyte era, and by 2020, the world is estimated to have about 40 zettabytes of data (IDC 2014).

It should be noted that Big Data is not just characterized by high volume, but also by complexity and variety (Helms 2015a; Laney 2001). In recoding individual and public activities digitally, some of the machine data—such as property records, tax records, health records, and phone records—are structured and well-defined, while others may be totally unstructured and do not have any predefined meaning and value (Ho et al. forthcoming).

Big Data also is characterized by the velocity and variability of analysis (Chen and Hsieh 2014; Gartner 2011; Laney 2001; TechAmerica Foundation 2012). Traditionally, data tasks including collection, documentation, organization, and analysis take a lot of time. It is common to have a delay of months or a couple of years between an event and obtaining some data and analytical results from the event. However, in the Big Data era, computing and data transmission technologies can potentially change the time span of a decision-making cycle by allowing real-time analysis of data to instantly inform decision making. This capability is particularly important in certain policy areas such as emergency management, health monitoring, hospital management, public health management, and disaster prevention and response.

With the possibility of real-time transmission and processing a large amount of data, Desouza (2014) suggests that the degrees of data variability and veracity differ significantly between the Big Data paradigm and the traditional paradigm of data analysis. Because data flow can change dramatically within minutes or hours, traditional analysis that is good for analyzing aggregated data over days, months, or years may not be valid or informative enough for problem detection and analysis. Also, given the pace and variability of data flow, the validity and relevance of data

to decision making has new meanings. For example, what is true and important can change dramatically within minutes in the data stream; therefore it requires more instant analysis to alert possible responsive actions to make the data truly useful for decision making.

Finally, Big Data emphasizes differentiation and personalization (Chen and Hsieh 2014). With a huge amount of data available about each service user or small geographical area, analysts can now drill down more deeply into the micro-level, such as the neighborhood level, parcel level, or individual level (Ho et al. forthcoming). For example, city officials can analyze how different policy domains are related to each other by joining together 311 complaint data, city service usage data, utility billing and payment data, housing value data, crime data, school performance data, and community survey data. They can use the results to identify geographical hotspots where city and county agencies, community organizations, and school districts need to coordinate more to enhance policy effectiveness in needier neighborhoods.

City agencies can also use Big Data from different sources to conduct predictive analytics and examine which property parcels may have a higher risk of being abandoned, or which households may face a growing risk of becoming homeless. Then based on the data results, cities may pursue proactive steps to help those households reverse the trend.

Another example of Big Data personalization is to use mobile phone apps to keep local residents more informed about current events, traffic conditions, crime, and public health alerts. City officials can use the global positioning satellite (GPS) function in smartphones and connected sensors embedded in different locations of a city to inform local residents more accurately about certain services. For example, residents can learn the arrival of the next bus or subway train, or where they can find the services they need, such as nearby public parking spaces or recreational programs in their neighborhoods.

These are just a few examples showing how Big Data can lead to new possibilities for service differentiation and personalization, allowing policymakers and managers to provide public services more effectively and responsively for different neighborhoods and individual citizens (Monroe et al. 2015). At the same time, the expanded use of Big Data opens up new ethical

Methodology

We analyzed the 30 most populous U.S. cities and a sample of 35 cities with populations between 100,000 and 500,000. Appendix I provides a list of these cities and their background information, such as population size and the form of government.

Extensive online research of these cities in spring 2016 helped us understand whether Big Data initiatives are being implemented. In addition, we analyzed policy documents related to Big Data initiatives, data usage and privacy concerns, interdepartmental and intergovernmental data collaboration, open data initiatives, web platforms for open data access, local entities' use of social media tools, and smartphone application use. To ensure data accuracy, two researchers separately and independently checked the data coding process. The preliminary data results were also sent to and verified by city officials involved.

In addition, in spring and summer 2016 we conducted surveys and phone interviews with city officials who are responsible for their respective cities' data initiatives. These interviews helped to provide a deeper understanding of the motivation, planning process, and organizational constraints of cities with Big Data initiatives. To ensure candid responses, we promised confidentiality to all participating officials in the survey and interviews.

and legal challenges, such as privacy, protection of individual rights, and prevention of subtle discrimination through data analytics algorithms (World Economic Forum 2012).

Purpose of the Study

This report explores how large and mid-sized U.S. cities have embraced Big Data to revolutionize:

- Program management
- Strategic planning
- Budgeting and resource allocation
- Performance measurement and reporting
- Public engagement and communication

Specifically, the report examines the following questions:

- Are cities collecting a lot of data through an array of channels, including sensors, social media, and mobile devices?
- Are cities using their data intelligently and using analytics, such as machine learning and predictive analytics, to improve program management, planning, and decision making?
- Do cities share their data with the public through open data platforms to make governmental operations more transparent and accountable and to enable idea crowdsourcing?
- Are cities collaborating with other cities, counties, and public or private organizations while implementing their Big Data strategies?
- Do cities visualize their data in a citizen-friendly way, such as through a performance dashboard or open budget platform, to foster greater public understanding of public policies and service outcomes?
- Do cities empower the general public to perform their own inquiries and analyses on their open data platforms?
- What organizational and governance factors influence cities' progress in embracing the Big Data movement, and what lessons can be learned from the experiences of early adapters?

A Framework for Big Data Initiatives

While technologies to capture, collect, and process data have advanced tremendously for the past two decades, the administrative process of handling data has remained largely unchanged in many local governments. For example, data still mostly reside in and are controlled by departments for specific purposes: Financial transaction data are housed by the finance department, utility bills and payment records are controlled and processed by city utilities or public works departments, nuisance complaint records are analyzed by the city hotline unit or 311 complaint center, library records are controlled by the library system, and public health data are controlled and analyzed by county health departments. Data collected by individual departments are seldom shared across departments and governmental boundaries.

The framework for Big Data initiatives challenges the departmental silos of data ownership and processing so that a more integrated and holistic perspective is used to gain new insights about program results, policy impacts, the quality of service delivery process, and the operating conditions of equipment, facilities, and services (DeSeve 2016). With appropriate analysis, integrated data can provide better understanding and actionable insights about public concerns that can supplement insights from traditional tools of policymaking, such as field observations by staff, citizen surveys, and neighborhood meetings.

The framework for Big Data initiatives has two major cycles (see Figure 1 on page 11):

- **The data cycle** governs the tools and processes used to collect, verify, and integrate data from multiple sources. Because of the variety of data sources involved, data teams in this cycle are often composed of representatives from multiple departments to leverage their field expertise and insider understanding of the data. In addition, new technologies—such as Hadoop, Hadoop-like technologies, stream analytics, massive parallel processing data warehouses, machine learning, and real-time analytics—are used in this cycle to process large and diverse types of complex data (TechAmerica Foundation 2012).
- **The decision-making cycle** starts after the data are cleaned, integrated, and analyzed. The results are interpreted and transformed by data teams into performance indicators or dashboards. In this cycle, data analytics results are provided to the decision-making units at the program, departmental, and enterprise levels, and evaluation results are used to inform policy goals and priority setting, budgeting, program management and resource allocation, and public reporting.

It should be emphasized that the decision-making cycle should not be merely the recipient of data analytics results. There should be two-way communication between the data cycle and the decision-making cycle; this ensures that policymakers' goals and priorities are used to set the policies and ethical guidelines of data analytics and to inform the priorities of data teams. Otherwise, the activities and results of data analytics may become less relevant or lack strategic significance to policymakers. Also, without input from policymakers and stakeholders, a city's data analytics team may use data collecting devices or processing methodologies that

City Government in a Data-Rich Environment

The advancement of computing technologies and Big Data analytics has provided exciting new possibilities for public management policymaking (Kamensky 2014). This is especially true for local governments today because they are operating in a data-rich environment. E-government initiatives and service digitalization for the past two decades have empowered most local governments in the United States with electronic record systems, online payment and transaction capability, and strong web presence.

Today, a typical city and county government together should have the following data that can be integrated and analyzed for policymaking and program management purposes:

Community and Business Development Data
- Local property records, including housing characteristics, value, and, possibly, conditions
- Business registration records
- Business and individual aggregated tax records
- Regulated activity permit applications and license records
- Pedestrian movement data collected by sensors

Public Safety Data
- Crime activities and police activity records
- 911 calls
- Traffic accident locations
- Photos or videos captured by traffic light cameras, police car cameras, and police officer-carried cameras

Health and Social Service Data
- Aggregated community health records
- Social service use and programming records

Environment and Energy Data
- Temperature and rainfall records
- Air quality records
- Water quality records
- Solid waste and recycling volume
- Residential, industrial, and commercial electricity consumption records
- Weather data collected by sensors

Education Data
- School district maps
- School performance records
- Schools' student demographic profiles
- Aggregated student attendance records

Culture and Recreation Data
- Library patron records
- Park and recreation program usage records
- Green space, hiking, and bike trail maps

City Infrastructure Data
- Public works projects records
- Traffic patterns in major street intersections
- Water and sewer service complaints
- Utility consumption records

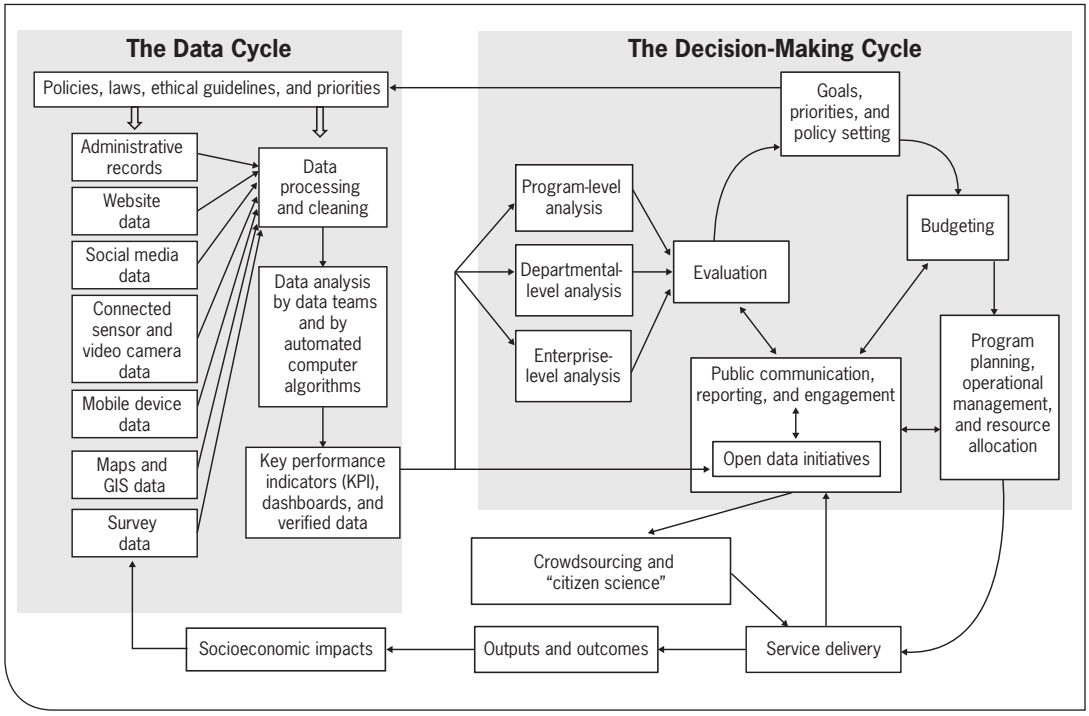
Utilities Data
- Aggregated consumption records
- Payment records
- Delinquency records

City Management Data
- Citizen satisfaction survey data
- City website usage and search history
- Public meeting records
- Social media text records
- Press releases and policy documents

The above data consists of two types:
- **Structured data**, such as records from administrative forms, financial transaction data, and caseload data
- **Unstructured data**, such as text data from social media, activity data from sensors, and sound and video data from connected cameras and drones

As technologies for digitizing information, processing, and interactions become more sophisticated and widespread, the availability and complexity of governmental data also increase significantly.

Figure 1: A Framework for Big Data Initiatives



are politically or socially unacceptable. That could cause embarrassment or political backlash that may outweigh the efficiency or effectiveness gains of data analytics.

Ideally, the decision-making cycle should be an open system that gives citizens more discretionary control in using and analyzing public data to impact service delivery, resource allocation, and policymaking. A key mechanism to achieve this goal is through a city's open data platform. Through open data initiatives, cities not only support the essential public values of transparency and participation, but they also encourage public-private collaboration, idea crowdsourcing, and citizen-initiated service delivery (Greenberg 2015; Harrison et al. 2012). As a result, the combination of Big Data and open data initiatives makes citizens not just the public service recipients or consumers, but also the co-designers, evaluators, and co-producers that partner with city agencies.

This report examines the extent to which U.S. city governments are trying to integrate the Big Data practices into their decision-making cycle. It also analyzes the barriers and challenges faced by local officials in these attempts. Based on our research, best practices from various local governments are provided to showcase how Big Data practices are impacting local government management and policymaking. In addition, a case study of Amsterdam (page 29) is presented to illustrate how Big Data initiatives can be integrated into a larger agenda of smart city development. Based on these analyses and lessons learned, the report concludes with specific recommendations for city governments.

The Data Cycle

Cities Are Collecting Data through an Array of Channels

Mining government website traffic data to assess citizens' services use. One of the fundamental building blocks of a Big Data system in local government is the organization's ability to collect and integrate many forms of data from multiple sources. As discussed above, local

governments possess structured and unstructured data, and one of the important sources of Big Data that is often underutilized is the usage pattern of government websites.

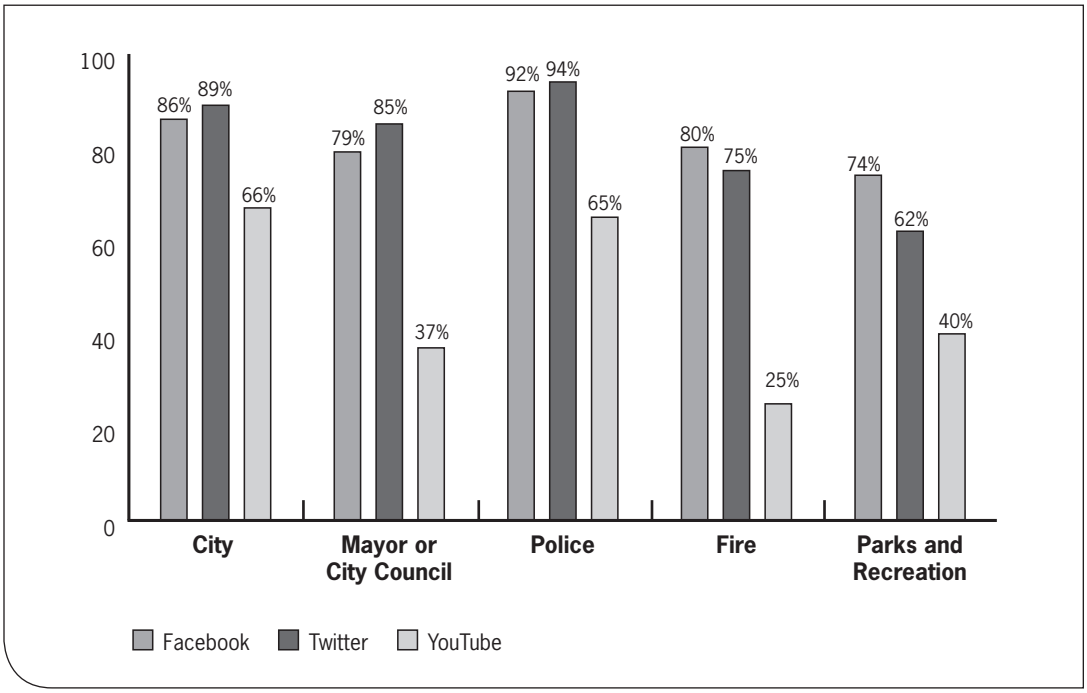
After decades of e-government initiatives, government websites have become a commonly used platform for government-citizen communication and transactions, such as submitting service requests, contacting local officials, registering for services and programs, downloading forms and information, and paying taxes and fees. As more citizens become "netizens" and regular users of online services, the traffic of government websites and their user patterns can provide useful information about what services the public wants most, who wants the services, and where and when those services are used or needed. Combined with other data and staff experiences, this type of analysis can lead to useful insights for restructuring governmental operations to best serve the needs and expectations of the public.

A number of local governments are using website traffic data to identify public priorities and concerns. For example, Albuquerque, Dallas, and Nashville have specific analytics programs to examine their websites' use patterns and even the devices that people use to access web services. They then use the results to inform departments about what online services are most popular among which types of users. A number of cities—such as Sacramento, California; Jacksonville, Florida; and Kansas City, Missouri—also rank web service usage and post the analytics results on their websites. That allows interested citizens to analyze the user pattern to see what services or policy issues have been popular over time.

Use of social media tools to understand citizen concerns and issues. In addition to government websites, many local governments rely on social media platforms to inform and engage the public (Gordon 2014). As seen in Figure 2, among the 65 cities examined in this report:

- 56 (86 percent) have a city Facebook page
- 58 (89 percent) have a city Twitter account
- 43 (66 percent) have a city YouTube account

Figure 2: Use of Selected Social Media Platforms



Some cities also let departments or city offices have separate social media accounts. A good example is the city of Los Angeles, which has many departmental social media channels for the public to use (see Figure 3). Among the various departments of the 65 cities studied in this report, police departments are most likely to have their own Facebook or Twitter accounts, followed by fire departments and parks and recreation departments. It is also very common for the offices of the mayors or city councils to have their own Facebook accounts (79 percent) or Twitter accounts (85 percent).

Compared with Facebook and Twitter, YouTube is relatively less common among departments, with the exception of the police. Among the 65 police departments examined, 42 (65 percent) have their own YouTube accounts to engage the public.

Given the widespread use of these social media tools, local governments are well-positioned to take advantage of the social media content and use text mining techniques to understand what citizens are most concerned about, what topics are trending in public discourse, and how their public relations team should respond and prioritize their focus. However, our interviews with various local officials suggest that most cities do not have the necessary staff capacity to track and analyze social media content. Those cities that use social media analysis for program and policymaking purposes often rely on third parties to serve their needs. Hence,

Figure 3: Los Angeles Contact Directory

Source: https://www.lacity.org/city-government/city-directory (accessed May 23, 2016)

despite the growing popularity of social media in government, there is still significant space and need for Big Data analytics to translate the engagement platforms into smart decision-making tools.

Use of smartphones and mobile devices to engage the public. Mobile phone technologies provide another great opportunity for local governments to engage the public, solicit information about service use and satisfaction, and partner with users to incorporate citizen-provided data in improvements to program management, planning, public communication, and customer service (Ganapati 2015; Nambisan and Nambisan 2013).

Residents in Boston can now use a smartphone app to measure road quality; they can send real-time data to the city about needs for specific street fixes and planning long-term investments (City of Boston 2015). Many major cities—such as New York, Los Angeles, and Seattle—have mobile apps for residents and visitors to check the schedules of subway trains and buses. Mobile apps are also used widely by cities to keep residents informed about local events, police alerts, or traffic issues, and to allow residents to pay fees and file complaints or service requests.

Detroit has launched a mobile app called "Improve Detroit," which allows users to report water main breaks, potholes, damaged street signs, and other local issues (see Figure 4). In the reporting process, the app uses the phone's location function to narrow down where the issues may be. Users can either type in the street address or drag the map to the location of the issue.

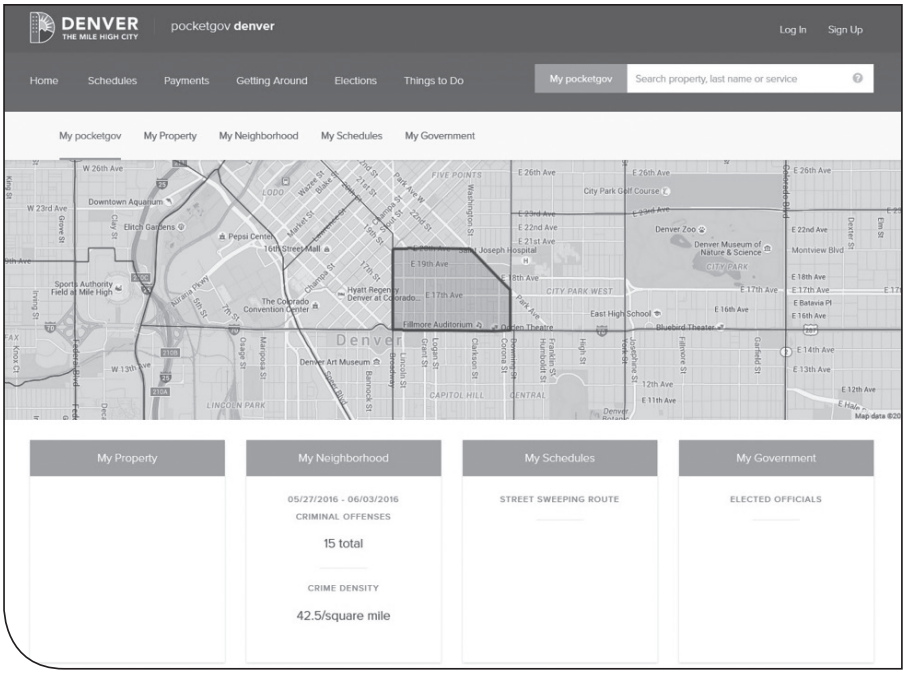
Figure 4: Improve Detroit Screenshot

Source: Improve Detroit Android App (accessed May 23, 2016)

Denver has a mobile phone app known as "PocketGov." Instead of using the city's website, which is anonymous and does not try to identify any user, PocketGov keeps information about a user's identity. It takes advantage of the user's profile and mobile features to provide a more customized, individualized experience (see Figure 5). For example, PocketGov knows a user's license plate and can tell the user when to renew.

Not all residents have computers at home, but most residents—including many low-income households and youth—have at least a smartphone, so mobile technologies like Improve

Figure 5: Denver PocketGov



Source: https://www.denvergov.org/pocketgov/#/address (accessed August 25, 2016)

Detroit or PocketGov are increasingly important for city governments to engage the public, receive feedback, and deliver services more responsively and conveniently.

Use of smartphone apps to engage the public has indeed become an emerging trend, especially among larger cities. Table 1 shows that out of the 65 cities studied, 24 offer one smartphone app, another 23 cities offer two to five apps, and some of the larger cities offer more than five apps. These numbers can change monthly due to new app initiatives.

Table 1: Cities That Offer Mobile Phone Apps (n=65)

Number of Mobile Phone Apps Offered	Frequency	Percentage
1	24	37%
2–5	23	35%
6–8	6	9%
9–14	3	4%
15 or more	4	6%
None	5	8%

It should be noted that the overwhelming majority of cities that offer mobile apps (51 out of 59) rely on third parties to develop the apps. Only 26 cities (43 percent) have the internal capacity to develop their own apps. This can be a potential concern from the perspectives of public engagement and data-driven decision making, because depending on the contractual agreement between cities and their third-party developers, city governments may not have free and direct access to the smartphone data. As a result, the city cannot capitalize on the data and user insights to improve service delivery and policy design.

Use of connected sensors and video cameras to collect data from the "Internet of Things." Connected sensors and video cameras offer another new source of Big Data for local governments. The use of sensors is not a recent phenomenon. For example, smoke detectors are a type of sensor that has been used by fire departments, businesses, and the general public for decades. In addition, water and sewer departments have been using sensors for many years to monitor potential problems with leaking pipes; plus, public works departments have been using weight sensors under road surfaces to monitor traffic flows and coordinate traffic light signals. Hence, using sensors to collect data is not a recent innovation.

What is relatively new and exciting in the use of sensor technologies today is the possibility to have massive deployment of these tools due to declining cost over time; the ability to capture greater variety, volume, and complexity of data; and the new technological possibility of connecting these sensors with broadband or wireless networks. Such a connection allows transmittal and processing of the captured data in real time for decision-making purposes.

These new possible uses, combined with data analytics, can be very helpful to local governments' program management and policymaking. In 2012, for example, New York City used monitoring sensors to detect elevated flow levels in sewer pipes and alert city staff to perform inspections and preventive maintenance (New York City 2012). In 2013, the city experimented with remote sensor technology to monitor the frequency and volume of sewer overflows and tried to use the data to guide future infrastructure investment (New York City 2013). In 2014, the City of Chicago, the University of Chicago, the School of the Art Institute of Chicago, and Argonne National Laboratory launched a new project using a network of 40 sensor nodes installed on lampposts to collect data on weather, air quality, light intensity, and the number of Wi-Fi and Bluetooth devices within a 100-foot range. The data were then joined and analyzed to understand pedestrian movements and public health concerns (Burns 2014).

Initiatives like these are spreading among many large and mid-sized cities. Table 2 shows that 52 of the selected 65 cities (80 percent) have some form of connected sensor initiatives, and they are not just used among public works departments. For example, among these initiatives, efforts in 29 cities are related to weather and environmental monitoring. Twenty-seven cities also use connected sensors to improve their transit and transportation systems. Initiatives related to public safety and justice or smart parking management are also popular. Most of these sensor initiatives are for public service delivery or quality of life issues in the community. Only seven cities have deployed connected sensors to support internal needs, such as projects related to smart governmental buildings.

The Kansas City, Missouri, Sensor Pilot Program

Kansas City, Missouri, has a pilot program using connected sensors in one of its downtown areas known as the Streetcar Corridor. The area has sensors and video cameras to monitor traffic flows and to manage streetlights and traffic signals. The city uses these sensors to measure vacancies in parking lots, snowfall impact, and the volume of pedestrian traffic. City officials therefore can understand the service needs of different areas instantly. The information will be used to inform city resource allocation more cost-effectively and responsively and to enhance local residents' and visitors' downtown experiences.

Downtown visitors can access essential information and data through touchscreen kiosks, which provide another way to engage the public and understand their informational needs. Furthermore, the city is partnering with companies and local entrepreneurs to form a new platform known as Kansas City Living Lab to encourage the use of the collected data to foster public innovation and develop start-up businesses to address urban issues and quality of life concerns.

Table 2: Cities with Sensor Initiatives (n=65)

Practice	Yes	Percentage
Have Any Sensor Initiatives?	52	80%
Specific Initiatives:		
Related to weather, environment, and energy	29	45%
Related to smart transit and transportation	27	42%
Related to public safety and justice	21	32%
Related to smart parking	20	31%
Related to nuisance monitoring	15	23%
Related to water and sewer	14	22%
Related to pedestrian traffic	11	17%
Related to smart buildings	7	11%

The Decision-Making Cycle

Cities Are Using Data in Decision Making

After collecting various types of data from various sources and processing the data to ensure reliability and accuracy, the next step in the decision-making cycle (see Figure 1 on page 11) is to analyze the data to produce relevant and useful information for managerial and policymaking purposes.

Traditionally, city analysts rely on descriptive statistics, such as means and percentiles, to look at data patterns, and they use the information to measure program performance and results. However, with the advancement of computing technologies and the emergence of many data analytics tools, there are more convenient and user-friendly platforms that can be used to conduct more sophisticated program and customer analysis, such as classification analysis, association and cluster analyses, anomaly detection, neural network analysis, dimensionality reduction, and various types of regression models.

Among the 65 cities examined in this report, 49 cities (75 percent) have reported some forms of data analytics initiatives. As seen in Appendix II, the majority (31) of the cities with initiatives rely on their information technology departments to take the lead. However, a few cities also have other departments to co-lead these initiatives with information technology departments, or they might even take the leading coordinator role. For example, six cities have involved the city manager's office or the mayor's office, and six cities let their performance management units coordinate various departments to pursue data analytics initiatives. Fifteen cities also have designated chief data officers. To foster coordination among departments and provide general policy direction for the city-wide data initiatives, 26 of the 49 cities have established a multi-departmental committee or team structure.

It should be noted that the scope, approach, and degree of sophistication of data analytics vary significantly among cities. Some have more elaborate initiatives involving multiple departments, programs, and external stakeholders. Others may only have one or two initiatives and only one department, such as the police, actively involved. Also, 28 cities (57 percent of those with analytics initiatives) have used a partnership with Code for America to launch pilot analytics programs.

Chief Data Officer

As data analytics demonstrates growing potential to contribute to policymaking, program management, citizen engagement, and organizational learning and innovation, cities have begun to create a chief data officer (CDO) position to lead their data initiatives. This position is different from chief information officer, chief technology officer, and chief performance officer positions. Typically, CDOs are responsible for the following tasks:

- Development and execution of multi-year, strategic data plans
- Coordination with different departments to establish an evolving data inventory
- Development and management of a city's open data portal
- Standardizing data, establishing data operating procedures, and managing data quality control
- Supporting the use of data analytics to optimize operational efficiency, inform policymaking, and unleash the potential of innovation
- Harnessing governmental and community resources to provide training and development opportunities for staff
- Securing data systems not only through procurement decisions but also through the development and implementation of proper work protocols and data accountability policies
- Overseeing the development of data governance such as data privacy issues, contracting practices, cross-sector partnerships, and legislative development

To achieve these tasks, CDOs need to work closely with other city officials, especially with chief information officers, chief technology officers, chief innovation officers, public communication officers, officials in the city's performance management unit, and data analysts from different departments. CDOs also need to reach out to different community stakeholders, such as "civic hackers"; representatives of federal, state, and local collaborators; and local businesses and civic organizations interested in data-driven decision making and data democratization.

In 2011, New York City was the first local government to create a CDO position. Since then, 14 other cities have followed the trend. Many CDOs have a background in technical fields, such as database management, statistical analysis, and computer programming. However, because CDOs also need to work closely with other city staff and community stakeholders with diverse backgrounds and interests, it is equally important for CDOs to master non-technical skills such as strategic planning, collaborative management, negotiation, personal networking, project management, ethical reasoning, and sensitivity to a community's core public values. CDOs are not data managers and their performance should not be measured by how much data they have created and managed. The ultimate responsibility of CDOs in local governments is to enable a community to harness the data potential from various sources and formats so that it can achieve organizational, policy, and community development goals more cost-effectively, responsively, innovatively, and collaboratively.

Among the 65 cities examined, a few cities can be regarded as pioneers in their analytics programs. For example, the City of Chicago has developed different forms of partnerships with educational and research institutions, state and federal agencies, and other local governments. It has used analytics to examine citizen complaints from its 311 center and various services at the neighborhood level (Goldsmith and Crawford 2014). It has also deployed predictive analytics to analyze resident complaints of rodent problems over 12 years, and it found that rodent problems are significantly related to trash overflow and cases of food poisoning in restaurants. This prompted the city in 2015 to deploy special sanitation teams more strategically and cost-effectively (Jeelani 2015).

Kansas City, Missouri, has also partnered with different university researchers to analyze crime data, nuisance complaint data, quarterly resident survey data, and census population and

housing data. That helps officials to understand how local resident perceptions of public safety and quality of life are related to service outcomes, public communication efforts, community engagement, neighborhood characteristics, and other city initiatives. The results provide new insights on how city services should be planned and organized more strategically and holistically (Ho et al. forthcoming; Ho and Cho 2016).

Los Angeles is another pioneer city in using analytics programs. Besides its crime tracking program, known as Los Angeles CompStat, the city launched its "Clean Streets Initiative" in 2015. It models after the police department's data-driven crime tracking system and brings in multiple sources of data to develop a street-by-street cleanliness assessment system. Based on the data results, the city's Bureau of Sanitation prioritizes resource allocation to improve the efficiency and cost-effectiveness of street cleanup strategies.

It should be noted that at present, most cities' analytics initiatives, whether they are done in-house or by third parties, are organized mostly on a project by project basis. The use of analytics across all city departments is rarely found, and many departments still lack the necessary staff capacity to handle sophisticated analytics work.

How Big Data Supports Open Government Initiatives

Cities Are Sharing Their Data through Open Data Platforms

Open data is another important Big Data strategy that may revolutionize local policymaking and program management. Many governments around the world are making their data openly available to the public. As of July 1, 2016, 50 out of the 65 cities studied (77 percent) have an open data platform. By allowing residents, businesses, community organizations, and other stakeholders to download, visualize, and analyze city data openly and freely, local governments enhance the transparency and accountability of their operations. In addition, they create new possibilities to crowdsource data analysis, generate innovative ideas, and foster partnerships among citizens, community organizations, and businesses to solve community challenges.

San Francisco has an open data platform that is very typical among cities. First, users can select whether they want to enter the data portal by areas of policy interest—such as economy and community, city management and ethics, public safety, or housing and buildings—or by departments. Once a user has selected a service, it shows a variety of data that are downloadable (see Figure 6).

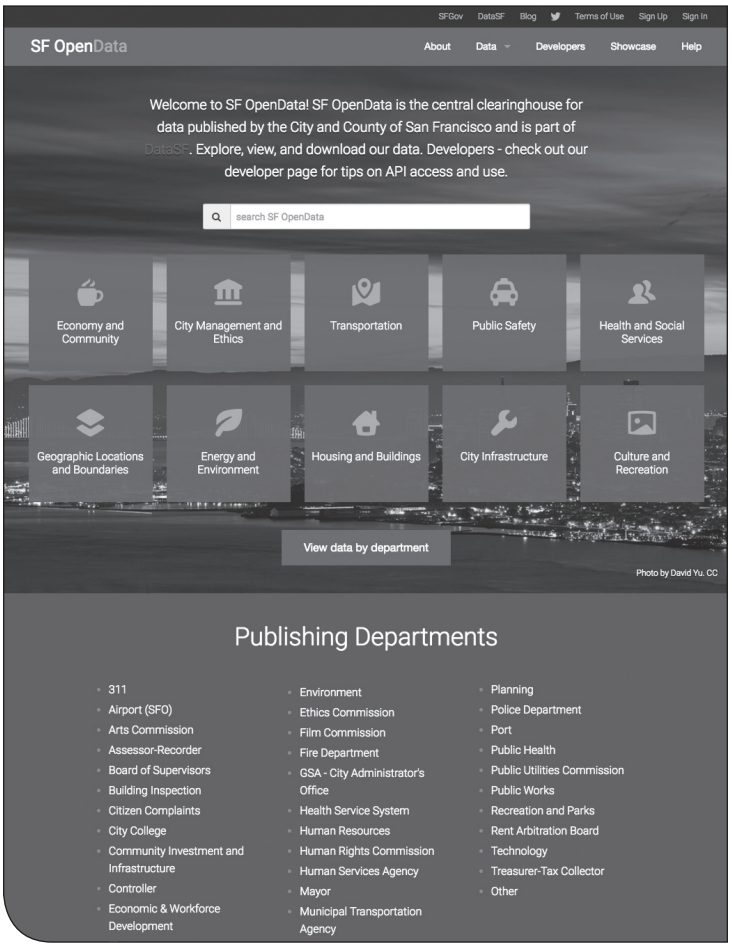
Cities Are Providing Citizen-Friendly Ways to Visualize or Access Data

While downloading data, maps, and policy documents is helpful to keep certain citizens and stakeholders more informed and engaged, most average citizens are not technically savvy and may not know how to use open data to conduct statistical analysis. To provide more value to the general public, open data platforms can provide citizen-friendly visualization tools so users can see data trends and patterns more conveniently, and they may even tailor the data presentation to specific concerns and interests.

A number of cities are indeed offering more citizen-friendly presentation of open data:

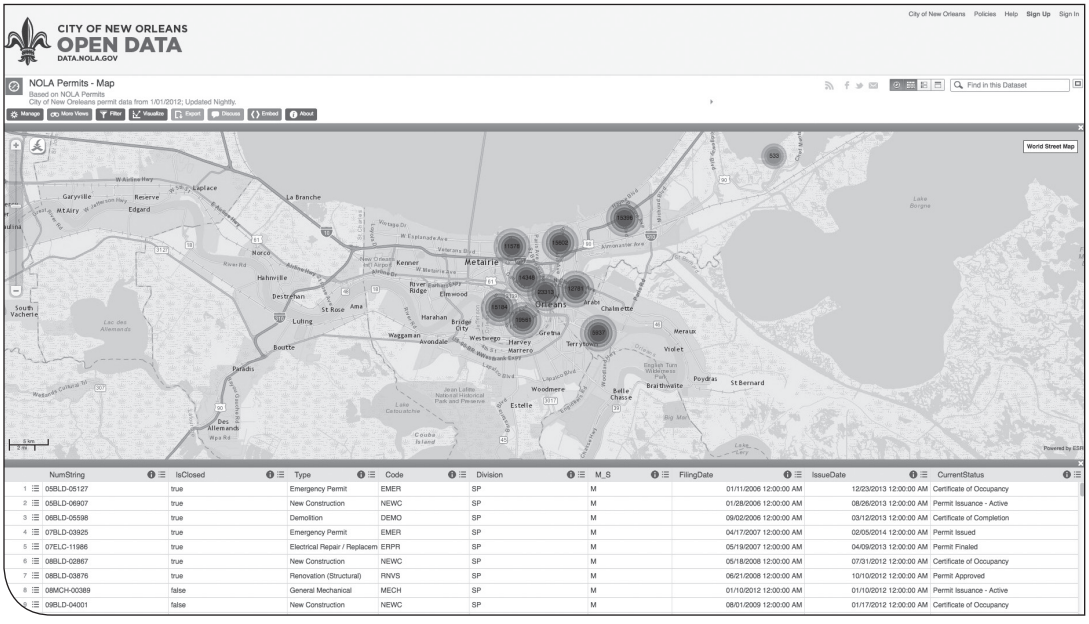
- **New Orleans, Louisiana,** has an open data platform that can potentially revolutionize city governments' public communication, engagement, and policymaking. In addition to the platform that allows users to download a variety of data on various topics—such as city finance and budget, economy and workforce, environment, health, education, social services, housing, and public safety—the city also visualizes some of the data by charts or maps (see Figure 7). Furthermore, to ensure that the data are useful and meaningful not just to statisticians or analysts but also to the public, policymakers, and stakeholders, the city presents the data analysis on a different website that focuses on service performance and policy results. On that website, users can see the policy goals and program objectives of different services and view the results of performance data analysis in a dashboard format to understand how well the city is doing in various areas and how tax money is used to serve the public (see Figure 8).

Figure 6: San Francisco OpenData Portal



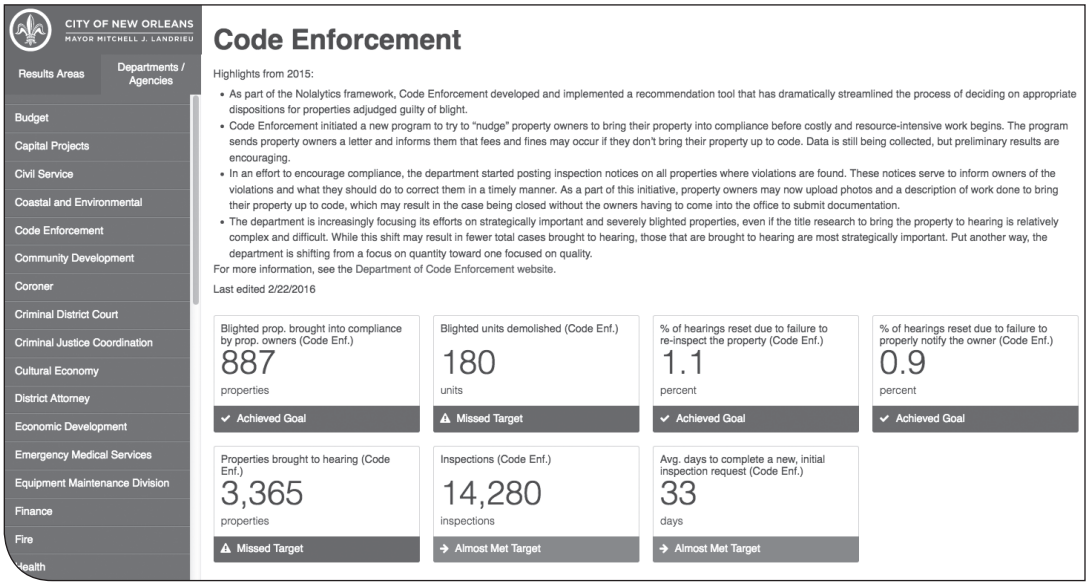
Source: https://data.sfgov.org/ (accessed August 25, 2016)

Figure 7: Data Visualization Examples from New Orleans



Source: https://data.nola.gov/dataset/NOLA-Permits-Map/u6yn-mk48 (accessed August 25, 2016)

Figure 8: Reporting Performance Results via ResultsNOLA



Source: https://results.nola.gov/dashboards#departments/t9i5-miys (accessed August 25, 2016)

- **Atlanta, Georgia,** is one of the cities which has open data platforms focusing on public budgeting and taxation data. The "Atlanta Budget Explorer" shows the revenues and expenditures of the city's general fund, enterprise fund, special revenue fund, and the trust and pension fund. Within the general fund, it also allows citizens to see the program allocation of departmental spending and program spending changes over time; all the data can be downloaded and shared (see Figure 9). To present the information in a user-friendly way, some of the data include infographics.
- **Louisville, Kentucky,** takes data access one step further and goes beyond data visualization. Working with the Civic Data Alliance, Louisville's Code for America Brigade, and the American Printing House for the Blind, the city provides open data about buildings, street addresses, parcels, manholes, power poles, and street crossings for civic hackers to help further develop a voice-driven navigation app called Nearby Explorer. The app has features built with the Global Positioning System (GPS) so blind users can choose to hear different location features as they move. Users can hear the distance and direction of nearby places as they approach streets and sites. This is another innovative way to provide citizen-friendly access to data.

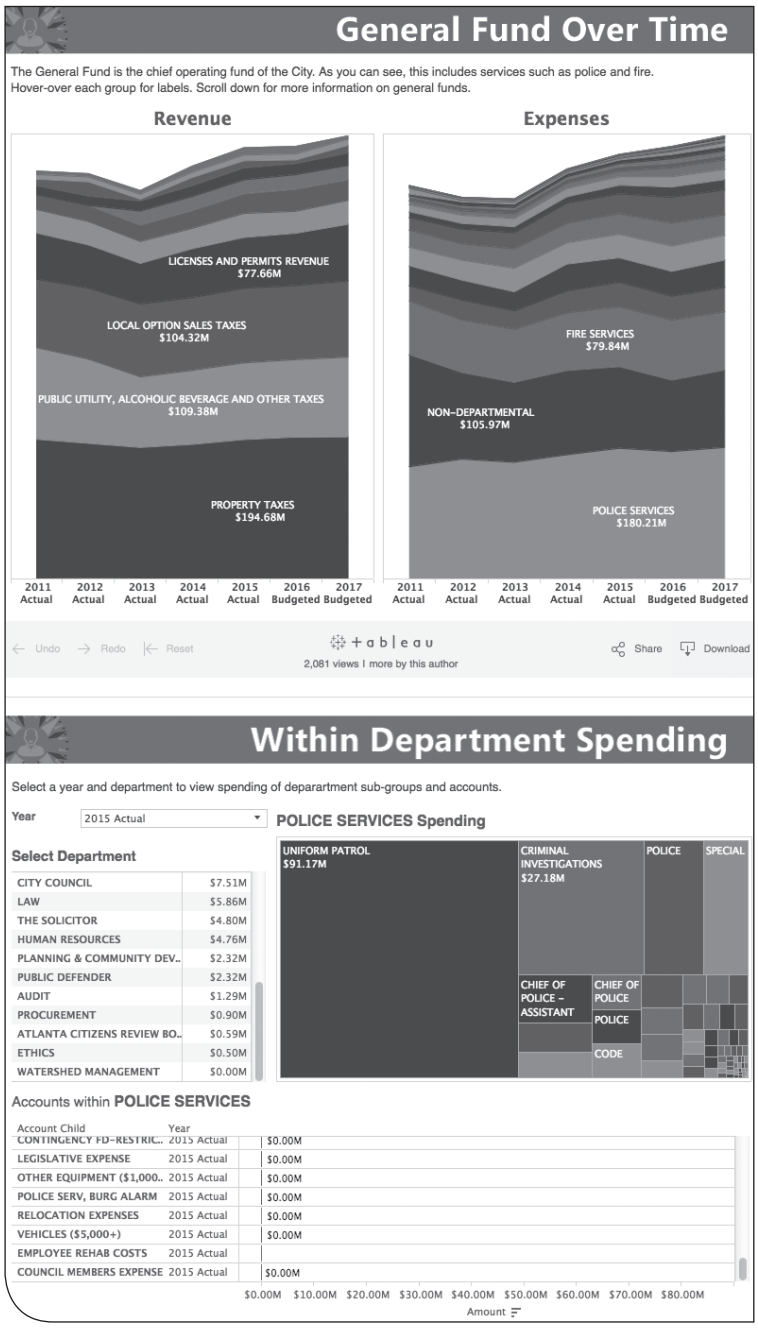
Cities Are Empowering Citizens to Conduct Their Own Data Inquiries and Analyses

In some of the open data platforms, cities also empower the public further by allowing them to do their own data inquiries. Users also can perform simple analytics to answer questions, such as how services perform in one neighborhood versus another or how service outcomes change over a specific period of time.

For example, on the open data website of Cary, North Carolina, data are categorized into several areas:

- Geographic information system (GIS) map data
- Spatial planning, building

Figure 9: Atlanta Budget Explorer



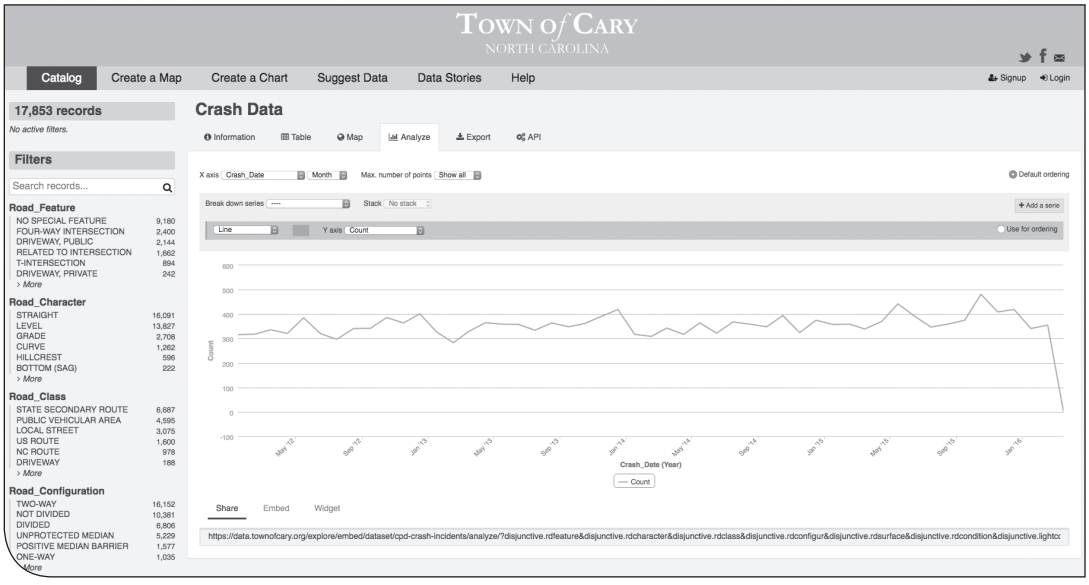
Source: http://ditweb.atlantaga.gov/abe/general.html (accessed August 25, 2016)

- Equipment and housing
- Government, administration
- City finance
- Economic development
- Business and employment
- Sports and leisure
- Police, public safety, and justice
- Culture and heritage
- Education, training, and research
- Environment
- Transports and movement

The website shows prominently the latest modifications to data and the most popular data and download statistics. More importantly, what is unique about Cary's open data platform is that it allows users to not only map the data or show the data in a table format, but also to analyze the data by day, month, or year and present a variety of summary statistics including the total count, average, standard deviation, minimum, or maximum of cases. Figure 10 shows an example using the town's monthly data of vehicle crashes from April 2012 to February 2016. By allowing users to visualize data in different ways, the open data platform gives users great flexibility and discretionary control in understanding a policy issue, even if they are not programmers and do not have a lot of statistical training.

Kansas City, Missouri, also has a data visualization and analytics platform that allows citizens to make their own data inquiries. The dashboard-like platform for code violation data shows all the violation cases geographically on a map (see Figure 11). It also shows different data trends, such as the number of open cases, the average number of days before closing a case,

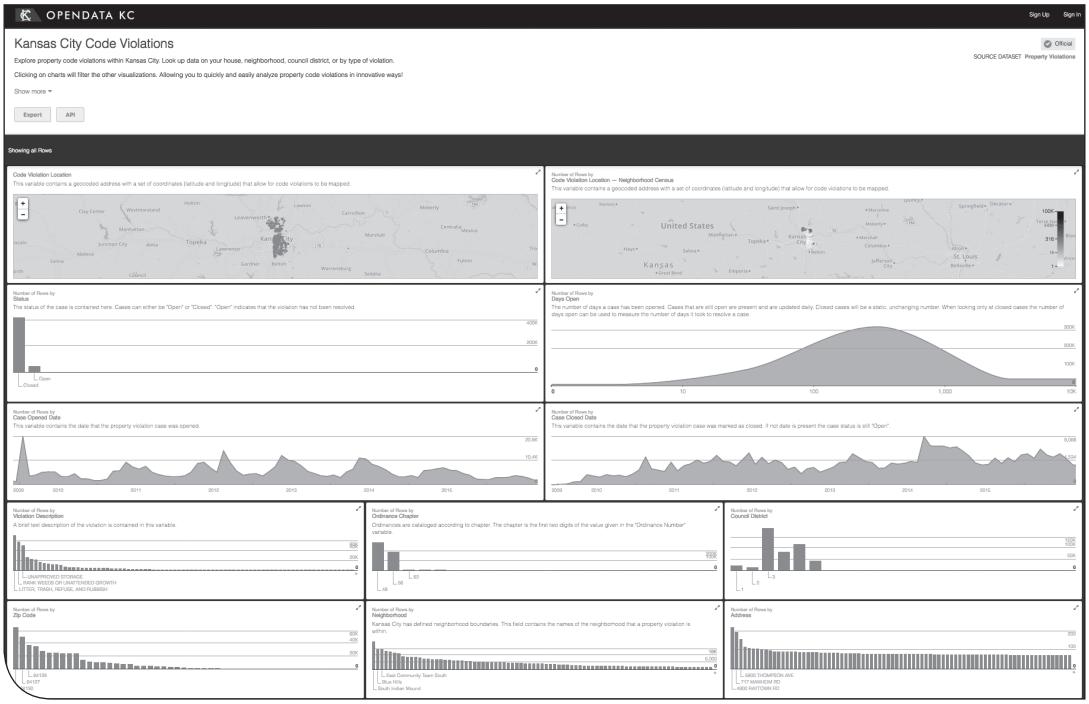
Figure 10: Town of Cary, North Carolina, Open Data Platform



Source: https://data.townofcary.org/explore/dataset/cpd-crash-incidents/analyze/ (accessed August 25, 2016)

and the number of cases closed over time. More importantly, it allows users to make inquiries of the data by a specific time of a year, by neighborhood, or by an exact address so they can check how many code violations a property or an area had previously. This platform can be very helpful to local residents, businesses, and potential home buyers who want to know more about the property condition in a neighborhood or in a specific location.

Figure 11: Platform for Code Violation Open Data Inquiries, Kansas City, Missouri



Source: https://data.kcmo.org/view/mnjv-uy2z (accessed August 25, 2016)

Organizational Factors and Strategies That Influence the Adoption of Big Data

The research for this report found that cities are pursuing Big Data initiatives with different emphases, scopes, and levels of sophistication. Many are using multiple channels to collect data and engage the public. Most cities are also using some forms of analytics to distill information and actionable insights from the data. However, some are more successful in engaging multiple departments and external stakeholders, while others are taking incremental steps and doing small-scale pilot projects to understand who should be involved in data analytics initiatives, what new tools and systems should be used, and how data analytics may impact decision making.

Based on interviews and a survey of selected local officials who are responsible for their cities' data initiatives, the following organizational factors and strategies are found to be important to support a city's Big Data practices and development.

Organizational Factors That Influence Adoption of Big Data

In our research, we asked cities about the biggest challenges they face in Big Data development. We found the staff capacity (factor two discussed below) ranked high on the obstacles to Big Data development. As seen in Table 3, other concerns included outdated IT systems, data quality concerns, and departments' willingness to use data analysis or to collaborate.

Table 3: Major Challenges of Big Data Development (n=24)

Concerns or Barriers	Agree or Strongly Agree	Neutral/ No Opinion	Disagree or Strongly Disagree
Giving sufficient staff training on data-driven decision making	67%	25%	8%
Hiring qualified programmers or data scientists	63%	33%	4%
Outdated IT systems or data interoperability	58%	38%	4%
Data quality and reliability	54%	42%	4%
Getting sufficient budgetary support	50%	38%	13%
Getting data support and collaboration from departments	50%	33%	8%
Getting departments to use the results of data analysis	50%	33%	17%
Security and system vulnerability	46%	29%	25%
Open data may lead to political risk and unanticipated vulnerability for the leadership	13%	42%	46%

Factor One: Leadership Attention

Support from top leadership—such as city managers, mayors, and other elected officials—is critical. These leaders set the vision for evidence-based, data-driven decision making, appoint managers to plan and oversee the execution of the vision, establish the necessary social infrastructure for collaboration, and encourage and incentivize departments to work together and to break the departmental silo mentality in data management (Kanter and Litow 2009; Nam and Pardo 2011).

For example, when Mayor Tong Yarber of Jackson, Mississippi, assumed office, he decided to change the culture of city administration and pushed for more data-driven decision making and public accountability. At the end of 2014, he appointed a 13-member committee to oversee open data governance and later launched the city's first open data portal. He also appointed a new director of innovation and performance to help his city focus on performance management, budget prioritization, and analytics initiatives. In August 2015, Jackson was selected by Bloomberg Philanthropies to be one of the first cohorts in the "What Works Cities" initiative. Other elected officials have also been the key champions of their cities' data initiatives, including Mayor Andy Berke of Chattanooga, Tennessee; former Mayor Michael Bloomberg of New York, New York; Mayor Jorge Elorza of Providence, Rhode Island; Mayor Kevin Faulconer of San Diego, California; Mayor Steven Fulop and Councilwoman Candice Osborne of Jersey City, New Jersey; Mayor Eric Garcetti of Los Angeles, California; Mayor Michael Hancock of Denver, Colorado; Mayor Sly James of Kansas City, Missouri; and Mayor Martin Walsh of Boston, Massachusetts.

In other cities, city managers or assistant city managers can play the critical leadership role. For example, Austin, Texas, has an executive committee for its data initiatives that consists of the director of water utilities, the director of planning and zoning, the chief innovation officer, the chief information officer, the chief communications officer, and the data architect. The committee is chaired by Assistant City Manager Rey Arellano, who works closely with Chief Information Officer Stephen Elkins, so that the executive committee can provide a strategic, enterprise-wide perspective on the direction and vision of the city's data initiatives. This signals to all city departments the importance of data-driven decision making. Other city managers, such as City Manager Chris Brady of Mesa, Arizona; City Manager Betsy Fretwell of Las Vegas, Nevada; City Manager Troy Schulte of Kansas City, Missouri; and Assistant City Manager Zach Walker of Independence, Missouri, have all been credited by their staff for their leadership roles in their cities' outcome- and data-driven decision-making initiatives.

Factor Two: Adequate Staff Capacity

Similar to the past experiences of e-government initiatives (Gil-García and Pardo 2005), one of the most commonly cited barriers to cities' Big Data development is staff capacity constraints. Because the idea of Big Data is relatively new and many analytical tools and software platforms are still emerging in the market, many cities have to hire new staff equipped with the latest technical and statistical training to keep up with these developments. They will also have to invest more in training and staff development to retool their existing staff, especially the data team in various service departments.

Enhancing staff capacity requires a significant financial commitment, which can be challenging when many local governments are struggling with sluggish economic recovery and have many competing demands for limited tax funds. As seen in Table 3, 67 percent of the responding cities agree or strongly agree that giving sufficient staff training on data-driven decision making is a major challenge, and 63 percent agree or strongly agree that hiring qualified programmers or data scientists is a major challenge.

Factor Three: Pursuit of Partners

Many cities pursue collaboration and partnership, which have been essential strategies in e-government initiatives to leverage opportunities and community assets to overcome organizational barriers (Gil-García and Pardo 2005). Amsterdam, Netherlands, is a good example, showing how city departments, business and community partners, and individual citizens can partner to use data results to learn, develop, and accelerate innovative solutions to complex urban problems. Experiences in Amsterdam and other global cities show that Big Data is more than the use of data and advanced statistical models in decision making. It is about smart governance, smart policies, and connectedness in a community.

Many of the 65 cities also pursue different kinds of data partnership strategies, including:

- Partnering with Code for America
- Networking with other cities to share program codes and experiences
- Partnering with local universities and private companies
- Partnering with community organizations

The data analytics team and the Performance Management Office of Kansas City, Missouri, have partnered with several of the region's universities and the Kansas City Code for America Brigade to pursue data-driven initiatives. Los Angeles also works with a university-based nonprofit organization, called "Team Six Thirty," to leverage expertise from community and business volunteers, students, and university researchers to pursue data analytics pilot projects. Providence, Rhode Island, has only eight staff members in the information technology department and faces many competing demands, so it also has relied on community partners since 2012. The partners—such as Code Island, a local brigade of Code for America—and the students and faculty members of local universities, have been helping the city to explore data analytics and pursue a robust open data initiative.

In addition, many of the 65 cities included in this study are members of the "What Works Cities" initiatives by Bloomberg Philanthropies, which provides consulting services to cities to support evidence-based policymaking. Many city officials interviewed highlighted the significance of this network. For example, Denver has developed some training materials on analytics and business improvement techniques. Through the network, other cities, such as Las Vegas, have been able to benefit from the materials that are tailored specifically to city management. Many cities in the network also share their pilot project experiences, programming tools, and policy documents with each other so that they can reduce the learning curve and build on what has already been done successfully. This type of inter-jurisdictional collaboration and resource sharing is another significant way to help cities overcome some of their capacity constraints and information gaps.

Organizational Strategies That Influence Adoption of Big Data

Strategy One: Governance Structures

To address ethical challenges and the social implications of Big Data development proactively, cities need to develop an open, transparent governance structure so that key stakeholders in a community, technical experts, and elected officials are involved in discussing the legal and ethical boundaries of data collection, usage, and dissemination. Also, clear and specific policy guidelines on data privacy should be developed not only for analysts and departmental managers of the government, but also for contractors and non-governmental partners in Big Data initiatives.

The Amsterdam Smart City Initiative

Amsterdam is a great example of a city seeking partnerships. Amsterdam Smart City (ASC) is a partnership of more than 100 private, governmental, educational, and community organizations, with the goals of improving the quality of life in the city, helping people live and work pleasantly, and facilitating more sustainable economic growth. Currently, it has close to 100 projects that cover these areas:

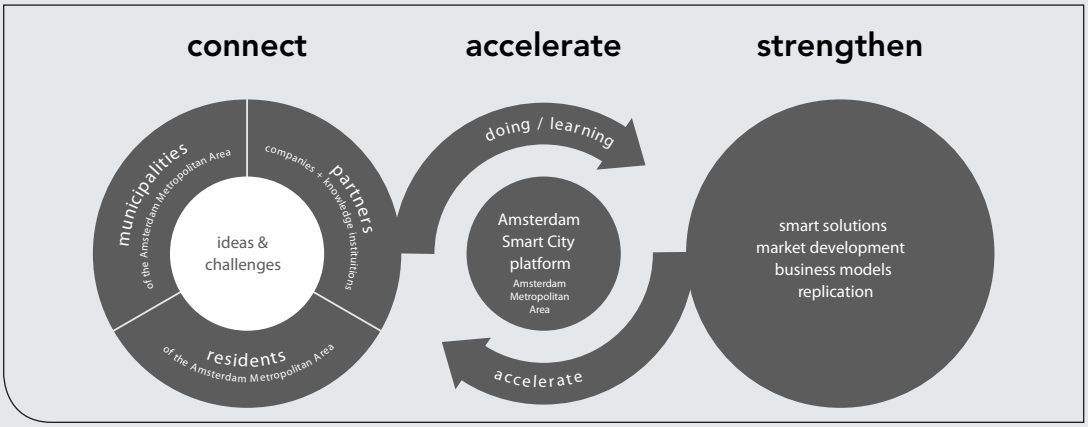
- Smart mobility
- Smart living
- Smart society
- Smart areas
- Smart economy
- Big and Open Data
- Smart infrastructure and living labs

Among these focus areas, its "Big and Open Data" initiative is most relevant to city government policymakers and managers. One of its projects, CitySDK, assists Amsterdam and other European cities with releasing their data, and it offers tool kits to develop digital services, such as performance dashboards and data visualization maps. What is unique about this initiative is that the project started in Amsterdam, but the partnership with the nonprofit organization Waag Society was designed to learn from the pilot experiences and then expand to other European cities, such as Helsinki, Manchester, Barcelona, Rome, Istanbul, and Lamia. That would allow quick dissemination of innovative ideas, and local governments across Europe can benefit from some economies of scale.

Similar to the U.S. cities' initiatives discussed above, Amsterdam Smart City also encourages the development of smartphone apps to engage citizens and to make public services more accessible and convenient. It encourages partnership with businesses, community organizations, and individuals to develop these apps, with special emphasis on these themes: safety, mobility, vacancy, energy, tourism and culture, and democracy.[1] It has organized open data and app development contests, and it worked with private and nonprofit sponsors to create the Smart Citizens Lab[2] to foster more collaboration between citizens, scientists, and designers to explore tools and applications that can be used to encourage smart living.

The Amsterdam example shows that Big Data initiatives, such as open data, app development, and analytics initiatives, should be connected to a strategic vision of smart city development and various policy initiatives. It should also focus heavily on smart governance, in which city departments, business and community organizations, and individual citizens partner with each other to use data results to learn, develop, and accelerate innovative solutions to complex urban problems (see figure below).

The "Smart Solution" Process of the Amsterdam Smart City Initiative



Source: https://www.amsterdameconomicboard.com/app/uploads/2016/02/Working-together-towards-ASC_drieluik_ENG_nov2014.pdf

1. http://amsterdamsmartcity.com/projects/detail/id/37/slug/apps-for-amsterdam
2. http://amsterdamsmartcity.com/projects/detail/id/108/slug/amsterdam-smart-citizens-lab

Our research shows that 34 of the 65 cities studied (52 percent) have posted open data policies on their websites, and 27 cities (41.5 percent) show data privacy policies. Also, according to our survey results, open data initiatives are primarily driven by the information technology department and the office of elected officials, such as the mayor's office. Only one-third of the 24 responding cities have involved representatives of community and nonprofit organizations, and 29 percent have involved citizen representatives in establishing the strategic plan of open data initiatives. Only one city has assistance from citizen representatives to oversee the execution of the city's open data initiative. Because Big Data touches upon many quality of life issues and has great privacy implications, public involvement and input are important. These findings suggest that there is still room for improvement in the governance structure of many cities' open data initiatives and data-driven decision making.

Table 4: Participants in the Governance Structure of Open Data Initiatives (n=24)

	Open Data Initiative Strategic Planning	Open Data Initiative Operation/Execution
Information technology department	71%	88%
Office of elected officials (e.g., the mayor)	54%	50%
City manager/county manager/chief administrator office	46%	46%
Performance management unit	38%	42%
Representatives of community and nonprofit organizations	33%	29%
Budget office or unit	29%	17%
Representatives of average citizens or neighborhoods	29%	4%
Planning department	25%	38%
Police	21%	33%
Information/communication	21%	21%
Graphical information system unit	17%	42%
Parks and recreation	17%	33%
A separate data analytics or data strategy unit	17%	21%

Strategy Two: Team Approach

As indicated earlier, one of the appealing features of Big Data is the possibility to connect many sources and types of data to harness useful information and actionable insights for decision making (Helms 2015a). However, to achieve this goal is not easy and requires a multi-departmental team approach so field experts and data staff from different departments can work together, share information about different data sets they manage, brainstorm ideas and strategies, and leverage each other's strengths and assets (Fountain 2016; Nam and Pardo 2011).

In Austin, Texas, the executive steering committee of data and information technology initiatives is assisted by two advisory councils. The first council is the Department Directors Advisory Council, which focuses on data strategies, information technology management concerns, and customer needs of different policy areas, such as public safety. The council consists of business directors of different policy departments. The second council is the Chief Information Officer (CIO) Council, which consists of the CIO and IT leadership from various departments. The council examines technical issues such as data standards, technological development, software needs, and hardware investment decisions.

The Austin councils provide a cross-departmental perspective on policy and technological needs and advise the city leadership on information technology procurement decisions. Under the two councils, there are also capabilities boards, such as the asset management board, the human resources management board, and the case management board. These boards look at specific managerial tasks and processes that cut across the needs of all service departments. The boards report to the Departmental Advisory Council and the Chief Information Officer Council. This type of governance structure helps Austin break the mentality of departmental silos and fosters more team building and citywide strategic dialogues about information technology development and data needs.

Strategy Three: Incremental Initiatives

Because Big Data is still an evolving field with many emerging possibilities of technical standards, analytical tools, and system deployment strategies, many cities are still exploring what may best serve their needs given their existing capacity and financial constraints. Therefore, many cities have decided to pursue Big Data initiatives incrementally, usually starting with some pilot programs, using limited resources to achieve quick wins, and then expanding gradually the scope of departmental involvement and project scales.

In this incremental learning process, two approaches are often used. The first approach is to use predictive analysis pilot projects, focusing on when and where crimes occurred, how different types of crimes cluster, and what factors are strongly associated with different crime types. For example, New York, Los Angeles, and Richmond, Virginia, have used data analytics to examine crime trends, conduct hotspot analysis, and help decide the strategic deployment of police resources (Mayer-Schönberger and Cukier 2013; Pearsall 2010; Perry et al. 2013). Because most police departments of large and mid-sized U.S. cities already collect a lot of data and are equipped with considerable staff and computing capacity, public safety is an attractive area for pilot analytics programs.

The second approach is to focus on nuisance issues. Many cities, such as Austin, Chicago, and Kansas City, started their Big Data initiatives with this type of focus. Because nuisance complaint data are readily available in most cities through their 311 complaint center, and failure to solve the problem is highly visible and can directly impact the quality of life and public perception, analytics pilot programs focusing on nuisance problems tend to draw the support of the top leadership and the general public more easily. Furthermore, because of the multi-faceted nature of nuisance problems—including garbage issues, illegal dumping, abandoned housing, and potholes—any effective and holistic solution is likely to require not only solid technical understanding of the problems but also multi-departmental collaboration and sound policy design. These challenges lend themselves naturally to the focus of Big Data, which is to harness actionable insights out of data from multiple sources and to incentivize departments to work together on evidence-based diagnosis and problem solving.

However, Big Data initiatives in cities are not limited to these two approaches. Individual cities have to decide which pilot programs fit most appropriately with the priorities and interests of elected officials and local constituencies. In 2015, for example, the city of Topeka, Kansas, decided to launch its open data and analytics initiative. It focused first on budgetary data and capital improvement projects because they had been getting a lot of citizen inquiries about public spending and taxation and the public benefits of governmental spending. Through the teamwork of the information technology department, the finance department, public works, and the performance management unit, Topeka launched its open data portal in 2015 to address the local constituency's interests. Within 14 months, the city received 147,000 webpage hits and more than 6.5 million record requests.

Hence, there is no one-size-fits-all strategy, but it is important to pursue incremental strategies that address the community's needs. For cities that have a decentralized approach in information technology management, pilot analytics programs are less likely to come from the city manager's office and be dictated by the information technology department. Instead, the information technology department and various service departments have to work together. In this organizational setting, the information technology department's role is to foster interdepartmental communication and collaboration and to provide the necessary support to help service departments see the value of data-driven decision making.

For example, the city of Dallas' information technology department develops a "use case" approach of Big Data initiatives and features individual projects or opportunities within departments to show how data analytics can be used to improve program efficiency, cost-effectiveness, and responsiveness. The information is then shared with the management teams in other departments to inspire new initiatives and interdepartmental dialogues about Big Data practices. Between January and July 2016, there were 32 use cases that covered a variety of issues, such as the city's recruitment process, neighborhood blight forecasting and risk analysis, wastewater flow forecasting, ambulance deployment optimization, and traffic accident hotspot analysis.

Strategy Four: Big Data Policies

While Big Data has led to many new possibilities for resource allocation optimization, customer service enhancement, and business process improvement, it has also created new ethical and legal challenges for both governmental and non-governmental actors, such as potential privacy and individual rights infringement; hidden inequity and discrimination in algorithm-driven decision making; and potential conflict between efficiency, customization, and equal access to service by all.

Through connected sensors and video cameras in public space, social media, and mobile apps, government agencies can now collect a lot of information about individuals, such as their location at specific times, daily habits, personal interests, ideological beliefs, and social circles. This type of information collection now raises important questions that policymakers and managers need to consider carefully as Big Data practices become more common in local government. These questions include:

- How should data be collected, stored, and analyzed?
- How should data be shared with non-governmental entities?
- How should data be integrated with other governmental records, such as driver license information, property records, voting records, tax records, and service usage and eligibility records?

Local governments are beginning to find answers to the questions above. In Chicago, for example, the city government and its community partners have launched a special initiative known as the Smart Chicago Collaborative to educate and engage the public about the city's Internet of Things (IoT) project, called "Array of Things." In June 2016, the collaborative organized two community meetings to get public feedback about the appropriate use of sensors in downtown Chicago, what policy guidelines and practices should be followed to secure the data and protect the privacy of individuals, and what governance structure should be in place to oversee the practice. Eighty residents attended these meetings and provided questions, comments, and suggestions. The collaborative also posted the meeting results online to receive additional comments from individuals and groups (Smart Chicago Collaborative 2016). The process was designed to uphold the principles of openness, transparency, and

public engagement so the public had a voice in determining the operating policies of Array of Things (City of Chicago 2016).

Seattle also integrates public engagement within its data governance structure. The city launched its privacy initiative in 2013, and it formed its first privacy advisory committee to advise the Chief Technology Officer (CTO) and an interdepartmental team on appropriate data practices. Because the committee consists not only of technical experts but also community representatives from different backgrounds—such as privacy lawyers, university researchers, business representatives, and representatives of advocacy groups—the committee provides important and diverse perspectives for the city in thinking about how data should be collected, retained, secured, and deleted across departments (Goldsmith 2015).

Implementing and Using Big Data in Cities

This report suggests that Big Data has begun to impact the decision-making cycle of the largest cities in the United States. Many officials in these cities who are responsible for data and information technology management are aware of these developments and their potential to optimize resource allocation and service responsiveness. Many have also begun to:

- Invest in new analytical tools and data systems
- Encourage departments to collaborate and share data
- Incentivize the use of data analytics and visualization

Among the 65 cities examined in this report, 49 have some form of data analytics initiatives or projects, 30 have established a multi-departmental team structure to do strategic planning for these data initiatives, and 28 have worked with Code for America to launch some pilot analytics programs.

In addition, many cities have begun to explore the use of connected sensors or video cameras to monitor environmental conditions, road usage and congestion, pedestrian traffic, parking vacancies, public safety conditions, and equipment status. Such monitoring helps cities to understand whether programs and services are operating at the desired level of sufficiency, efficiency, and effectiveness. Most of these large cities are also using at least one mobile app to engage the public.

Finally, open data initiatives are commonly found among large and mid-sized cities. These platforms allow the public to download data, maps, and policy documents; they also keep citizens more informed about the results of budgetary decisions and service delivery. A few cities allow users to analyze and visualize data by maps, tables, and charts and to customize the geographical scope and time span of the analysis based on their interests or concerns.

Hence, the Big Data era of local management has already emerged among large and mid-sized cities in the United States, even though the scope, focus, and pace of development may vary from city to city. As more tools and platforms of Big Data analytics become more readily available and user-friendly, it is foreseeable that data analytics and visualization will be more commonly used, not just by statisticians and data scientists, but also by departments' operational managers and program analysts—or even by average citizens—to understand the needs, output, and results of public services (Greenberg 2015).

Because Big Data's purposes and practices are very diverse among cities, it is difficult to develop a one-size-fits-all approach for city strategies. Many factors, such as policy priorities, organizational capacity, leadership support, and community expectations, should be considered carefully in establishing a policy agenda and strategies for Big Data development. However, through survey analysis and interviews, a few policies and managerial practices are found to be important to cities that embrace Big Data development. These policies and practices include the following recommendations for city leaders and executives.

Recommendations for City Leaders

Recommendation One: City leaders should think about a "smart city system," not just data.

It is important for policymakers to consider Big Data as a part of a holistic approach toward smart city development, not just a data initiative (Kanter and Litow 2009; President's Council of Advisors on Science and Technology 2016). A "smart city" refers to an urban environment in which the critical infrastructures—including roads, bridges, communications, water, and power—and various services—including public safety, transportation, education, healthcare, and city administration—are interconnected by different technologies. These components' data should be integrated and analyzed as a system through different mechanisms, including machine learning mechanisms. That can potentially make city services more efficient, effective, responsive, and sustainable (Chourabi et al 2012; Hall 2000; Harrison et al. 2000; Kanter and Litow 2009).

Recommendation Two: City leaders should demonstrate executive commitment to evidence-based policymaking.

An underlying premise of Big Data applications in government is that policymakers and city leadership want evidence-based policymaking. They believe that having more reliable, valid, and time-sensitive data and applying better analytics to understand the data are essential to the core mission of their organization. Establishing such a vision and articulating this commitment to departmental staff is necessary for effective deployment of enterprise-wide Big Data strategies (Helms 2015b). Otherwise, Big Data initiatives will not be taken seriously by departmental staff and may only become piecemeal efforts that have limited impacts on governmental operations and policymaking.

Recommendation Three: City leaders should institutionalize Big Data development.

One way to demonstrate mayoral and council commitment to evidence-based policymaking and Big Data development is to institutionalize open data, the use of analytics, and the practices of public performance reporting and data privacy protection. According to our survey, 34 of the 65 cities studied have specific legislation, executive orders, or resolutions that are related to open data, and eight cities have specific legislative or mayoral support related to data analytics initiatives. These efforts not only signal to departments and the public the importance of data-driven policymaking, but they also help to institutionalize Big Data development in the long run. Furthermore, they help set priorities for departments in resource allocation despite possible future changes in the city council or in the managerial leadership.

Recommendation Four: City leaders should encourage a culture of bottom-up innovation and anticipatory change.

An analysis of Big Data practices and our survey findings shows that cities that encourage bottom-up innovation, promote a culture of anticipatory change, pay close attention to trends and developments outside their organization, and do not mind learning by doing are more likely to be the first adopters of Big Data practices. They are also more likely to demonstrate more breadth and depth in their Big Data strategies. Because Big Data is still a relatively new development, willingness to experiment with new ideas and commit to learning by doing are critical (Helms 2015b). City leadership needs to foster this type of culture among employees and encourage them to take ownership of the technological change. That would help their organization adapt more quickly and effectively.

Recommendation Five: City leaders should involve the public in data governance.

It is important to involve citizens, key community stakeholders, policymakers, and technical experts to understand what data should be made public, and how data should be analyzed and visualized for public consumption. Citizen voices should also be listened to when considering the legal and ethical implications of Big Data. Having citizen representation on special task forces or committees that deal with data governance issues is a good practice so that their input can help policymakers and city leadership think about the appropriateness of Big Data policies from the public's perspective.

Recommendations for City Executives

Recommendation Six: City executives should build a multi-departmental team to develop Big Data strategies.

No single city department has all the data and technical capacities to handle all the essential tasks of Big Data analysis, and different city databases may use different data systems and standards. Therefore, collaboration among specialized field experts is important as that helps avoid data misinterpretation, find out how different datasets should be joined, and how the data should be analyzed statistically. A team approach involving the information technology department, representatives of the city leadership, and representatives from different service departments is a good practice in the planning, coordination, and management of Big Data strategies.

Recommendation Seven: City executives should invest in collaborative capacity building.

Capacity building, especially in staff training and system development, is necessary not only within the information technology department but also among all service departments. Because of fiscal and administrative constraints, interdepartmental, intersectoral, and intergovernmental collaboration are necessary. Departments should share their programming expertise and statistical knowledge. Through regional and national networks such as What Works Cities by Bloomberg Philanthropies and the Smart Cities Initiative by the White House, local governments, state agencies, and federal agencies may also work together to share experiences, innovative solutions, and other tacit knowledge about Big Data usage and applications.

Recommendation Eight: City executives should designate regular representatives to network with others.

Because collaboration and networking are so important to gaining insights and leveraging limited resources to build capacity in the rapidly changing world of Big Data, designating specific departmental representatives to work with each other regularly is important. Forming regular contacts among departmental representatives and with external stakeholders helps build familiarity and trust. It also reduces social barriers to communication and information exchange. Hence, if possible, departments should avoid rotating different people to attend data team meetings and stakeholder meetings related to Big Data initiatives.

Recommendation Nine: City executives should develop a multi-year strategic data plan.

After developing a data inventory of different city departments and knowing more about how different data can be used and analyzed, departments should work with each other and with the information technology department to develop a data strategic plan that spans at least 18–24 months. The plan should lay out specifically which data will be made public in the open data portal, what new data will be developed by which departments, what hardware and software should be purchased, and what training program and staff changes will be

needed. The plan also should specify the time frames for different activities and designate specific staff that will be held accountable for progress and results. Having a multi-year roadmap of Big Data strategies and clear performance benchmarks for data management projects will help departments make steady progress over time.

Recommendation Ten: City executives should communicate to citizens the information gained from Big Data initiatives.

To make open data and data analytics more relevant to policymakers and the general public, departmental analysts cannot think about Big Data merely as statistical analysis exercises. Results from open data initiatives and analytics programming need to have real-life stories that highlight the work's policy implications and community significance so the general public can more effectively connect data-driven policymaking with their daily life.

The dangerous buildings demolition project in Kansas City is a good example. City staff in the Performance Management Office regularly analyze 311 complaint data and quarterly survey data. In 2015, they noticed that local residents were demanding that the city focus more on demolishing vacant structures on the dangerous building list. To foster more public dialogue about this issue, city staff posted the data results on the city's open data portal and showed the time trend of dangerous building cases and a heat map of their locations in the city. Also, the city's chief data officer created a blog to talk about the stories behind the data, the policy significance of the findings, and the implications for city actions and budgetary decisions in response to the problem (Roche 2016). This, in turn, generated more public interest in seeing the data results on the city's open data platform, thus connecting data analytics more closely with evidence-based policymaking, public engagement, and community building. This is an example showing that data analytics is not only about statistical analysis; the real policy impact also relies on the effectiveness of public engagement and the story behind the data.

Conclusion

Cities need to develop a larger vision of Big Data and see data analytics as part of a smart city movement, not just as data management and statistical programming. While the integration of a massive amount of data and the effective use of large-scale computational analysis of data are important, they are just tools and operations to the ultimate goal: to use data as a language or as a community building platform to transform organizational culture, optimize program performance, break down the government department silos, and promote innovative problem-solving (Chenok et al. 2013; Kamensky 2015).

Policymakers and managers should also understand that Big Data has significant governance implications (Kanter and Litow 2009). Big Data opens up new possibilities for interoperability and intergovernmental and intersectoral thinking (Pardo, Nam, and Burke 2012; Fountain 2016). A lot of complex policy problems cities face, such as crime, poverty, economic development, transportation, and environmental protection, are caused and constrained by regional and socioeconomic factors that are beyond the control of a single city or county.

Big Data initiatives provide a new platform for policymakers, key stakeholders, and individual citizens to use data to understand these problems more holistically. The initiatives also foster dialogues that can potentially cut across the boundaries of cities, counties, school districts, special districts, the business sector, and the nonprofit sector, as well as across the separate layers of local, state, and federal agencies (Fountain 2016; Kamensky 2015). Currently, cities' open data initiatives or data analytics efforts have not fully realized this potential. Most of the initiatives implemented by the 65 cities examined in this report have remained largely the effort of a local jurisdiction. Only a few cities, such as Austin, Los Angeles, New York, and

New Orleans, have launched data initiatives that move toward cross-boundary, data-driven policymaking.

Given the current status of development, applications of Big Data tools still have a lot of untapped potential among city governments. In addition to more investment to enhance various departments' technical capacities, city officials should also explore carefully some of the legal, ethical, and governance implications of Big Data. This will ensure that various applications are not only administratively and technically feasible but also socially and politically acceptable to community members and key stakeholders.

Appendix I: List of Cities Examined

City	2014 Population	2014 U.S. City Population Ranking	Form of Government	City Website	Assisted in the Survey Process	Assisted in the Interview Process
New York, NY	8,491,079	1	Mayor-Council	www1.nyc.gov/		
Los Angeles, CA	3,928,864	2	Mayor-Council	www.lacity.org/	Yes	Yes
Chicago, IL	2,722,389	3	Mayor-Council	www.cityofchicago.org/		
Houston, TX	2,239,558	4	Mayor-Council	www.houstontx.gov		
Philadelphia, PA	1,560,297	5	Mayor-Council	www.phila.gov		
Phoenix, AZ	1,537,058	6	Council-Manager	www.phoenix.gov	Yes	
San Antonio, TX	1,436,697	7	Council-Manager	www.SanAntonio.gov		
San Diego, CA	1,381,069	8	Mayor-Council	www.sandiego.gov	Yes	
Dallas, TX	1,281,047	9	Council-Manager	www.dallascityhall.com		Yes
San Jose, CA	1,015,785	10	Council-Manager	www.sanjoseca.gov	Yes	
Austin, TX	912,791	11	Council-Manager	www.austintexas.gov/	Yes	Yes
Jacksonvillle, FL	853,382	12	Mayor-Council	www.coj.net/		
San Francisco, CA	852,469	13	Mayor-Council	www.sfgov.org	Yes	
Indianapolis, IN	848,788	14	Mayor-Council	www.indy.gov		
Columbus, OH	835,957	15	Mayor-Council	www.columbus.gov/		
Fort Worth, TX	812,238	16	Council-Manager	www.fortworthtexas.gov	Yes	Yes
Charlotte, NC	809,958	17	Council-Manager	http://charmeck.org		
Detroit, MI	680,250	18	Mayor-Council	www.DetroitMI.gov	Yes	
El Paso, TX	679,036	19	Council-Manager	www.elpasotexas.gov		
Seattle, WA	668,342	20	Mayor-Council	www.seattle.gov		
Denver, CO	663,862	21	Mayor-Council	www.denvergov.org	Yes	Yes
Washington, DC	658,893	22	Mayor-Council	www.dc.gov		
Memphis, TN	656,861	23	Mayor-Council	www.memphistn.gov/		
Boston, MA	655,884	24	Mayor-Council	www.cityofboston.gov	Yes	Yes
Nashville, TN	644,014	25	Mayor-Council	www.nashville.gov		
Baltimore, MD	622,793	26	Mayor-Council	www.baltimorecity.gov/	Yes	
Oklahoma City, OK	620,602	27	Council-Manager	www.okc.gov		
Portland, OR	619,360	28	Commission	www.portlandoregon.gov		
Las Vegas, NV	613,599	29	Council-Manager	www.lasvegasnevada.gov	Yes	Yes

City	2014 Population	2014 U.S. City Population Ranking	Form of Government	City Website	Assisted in the Survey Process	Assisted in the Interview Process
Louisville, KY	612,780	30	Mayor-Council	www.louisvilleky.gov	Yes	Yes
Albuquerque, NM	557,169	32	Mayor-Council	http://www.cabq.gov/	Yes	
Tucson, AZ	527,972	33	Council-Manager	https://www.tucsonaz.gov/		
Fresno, CA	515,986	34	Mayor-Council	http://www.fresno.gov/	Yes	
Sacramento, CA	485,199	35	Council-Manager	http://cityofsacramento.org/		
Kansas City, MO	470,800	37	Council-Manager	http://kcmo.gov/	Yes	Yes
Mesa, AZ	464,704	38	Mayor-Council	http://www.mesaaz.gov/	Yes	
Atlanta, GA	456,002	39	Mayor-Council	http://atlantaga.gov/	Yes	
Colorado Springs, CO	445,830	42	Mayor-Council	https://coloradosprings.gov/		
Miami, FL	430,332	44	Mayor-Council	http://www.miamigov.com/		
Oakland, CA	413,775	45	Mayor-Council	http://www2.oaklandnet.com/		
Tulsa, OK	399,682	47	Mayor-Council	https://www.cityoftulsa.org/		
New Orleans, LA	384,320	50	Mayor-Council	http://www.nola.gov/		
Lexington, KY	310,797	61	Urban County (resembles Mayor-Council)	http://www.lexingtonky.gov/		
Cincinnati, OH	298,165	65	Mayor-Council	http://cincinnati-oh.gov/		
Saint Paul, MN	297,640	66	Mayor-Council	https://www.stpaul.gov/		
Jersey City, NJ	262,146	74	Mayor-Council	http://www.cityofjerseycity.com/	Yes	
Fort Wayne, IN	258,522	77	Mayor-Council	http://www.cityoffortwayne.org/		
Durham, NC	251,893	81	Council-Manager	http://durhamnc.gov/		
Baton Rouge, LA	228,895	96	Mayor-Council	http://www.brgov.com/		
Rochester, NY	209,983	103	Mayor-Council	www.cityofrochester.gov		
Salt Lake City, UT	190,884	124	Mayor-Council	http://www.slcgov.com/		
Worcester, MA	183,016	131	Council-Manager	http://www.worcesterma.gov/		
Providence, RI	179,154	134	Mayor-Council	http://www.providenceri.com/	Yes	Yes
Fort Lauderdale, FL	176,013	135	Council-Manager	http://www.fortlauderdale.gov/		
Chattanooga, TN	173,778	141	Mayor-Council	http://www.chattanooga.gov/	Yes	
Jackson, MS	171,155	143	Mayor-Council	http://www.jacksonms.gov/	Yes	Yes
Cary, NC	155,227	160	Council-Manager	http://www.townofcary.org/		
Sunnyvale, CA	149,980	168	Council-Manager	http://sunnyvale.ca.gov/		
Hampton, VA	136,879	189	Council-Manager	http://www.hampton.gov/		
Columbia, SC	132,067	195	Council-Manager	http://www.columbiasc.net/		
Topeka, KS	127,215	213	Council-Manager	http://www.topeka.org/	Yes	Yes
Hartford, CT	124,705	218	Mayor-Council	http://www.hartford.gov/		
Independence, MO	117,494	231	Council-Manager	http://www.ci.independence.mo.us/	Yes	
Rochester, MN	111,402	249	Mayor-Council	http://www.rochestermn.gov/		
Richmond, CA	108,565	265	Council-Manager	http://www.ci.richmond.ca.us/		

Appendix II: Cities Reporting Specific Data Initiatives (as of July 1, 2016)

City	Organizational Unit(s) or Person(s) in Charge of Data Initiatives	Analytics Focus: Program Management and Planning	Integration with Budgeting	Using a Team Approach or Multi-Departmental Governance Structure in Data Initiatives	Have a Chief Data Officer	Partnership with Code for America
Albuquerque, NM	Information Technology	Yes		Yes		Yes
Atlanta, GA	Office of Innovation Delivery and Performance	Yes	Yes	Yes		Yes
Austin, TX	Assistant City Manager, Information Technology	Yes	Yes	Yes		Yes
Baltimore, MD	Chief Data Officer	Yes	Yes	Yes	Yes	
Baton Rouge, LA	Information Technology		Yes			
Boston, MA	Mayor's Office, Information Technology	Yes	Yes	Yes	Yes	Yes
Cary, NC	Information Technology	Yes				
Charlotte, NC	Information Technology					Yes
Chattanooga, TN	Information Technology	Yes		Yes		Yes
Chicago, IL	Information Technology	Yes		Yes	Yes	Yes
Cincinnati, OH	Chief Data Officer	Yes		Yes	Yes	
Colorado Springs, CO	Information Technology	Yes				
Dallas, TX	Information Technology	Yes	Yes	Yes		
Denver, CO	Mayor's Office, Chief Performance Officer	Yes	Yes	Yes		Yes
Detroit, MI	Information Technology	Yes		Yes	Yes	Yes
Durham, NC	Chief Data Officer	Yes			Yes	Yes
Fort Lauderdale, FL	Police	Yes				

City	Organizational Unit(s) or Person(s) in Charge of Data Initiatives	Analytics Focus: Program Management and Planning	Integration with Budgeting	Using a Team Approach or Multi-Departmental Governance Structure in Data Initiatives	Have a Chief Data Officer	Partnership with Code for America
Fresno, CA	Information Technology	Yes	Yes			
Houston, TX	Information Technology, Performance Improvement Division	Yes	Yes	Yes	Yes	
Indianapolis, IN	Information Technology					Yes
Jackson, MS	Director of Innovation and Performance	Yes	Yes	Yes		
Jacksonville, FL	Information Technology	Yes	Yes			
Kansas City, MO	Office of Performance Management, Chief Data Officer	Yes		Yes	Yes	Yes
Las Vegas, NV	City Manager's Office	Yes	Yes	Yes		Yes
Lexington, KY	GIS					Yes
Los Angeles, CA	Mayor's Office, City Controller, Information Technology, Chief Data Officer	Yes	Yes	Yes	Yes	
Louisville, KY	Information Technology	Yes	Yes	Yes		Yes
Mesa, AZ	Individual Departments	Yes	Yes			Yes
Memphis, TN	Information Technology, Police	Yes		Yes		
Miami, FL	Information Technology					Yes
Nashville, TN	Information Technology			Yes		Yes
New Orleans, LA	Information Technology, Performance and Accountability	Yes		Yes	Yes	Yes
New York, NY	Chief Data Officer	Yes		Yes	Yes	Yes
Oakland, CA	Information Technology					Yes
Phoenix, AZ	Information Technology			Yes		
Philadelphia, PA	Chief Data Officer	Yes		Yes	Yes	Yes

City	Organizational Unit(s) or Person(s) in Charge of Data Initiatives	Analytics Focus: Program Management and Planning	Integration with Budgeting	Using a Team Approach or Multi-Departmental Governance Structure in Data Initiatives	Have a Chief Data Officer	Partnership with Code for America
Providence, RI	Mayor and a Council Member, Chief of Policy and Innovation, Information Technology			Yes		Yes
Richmond, CA	Police	Yes				
Rochester, MN	Police	Yes				
Rochester, NY	Information Technology	Yes				
Sacramento, CA	Information Technology		Yes	Yes		
Saint Paul, MN	Information Technology, Police	Yes				
San Antonio, TX	Information Technology, Police	Yes				Yes
San Diego, CA	Chief Data Officer		Yes		Yes	Yes
San Francisco, CA	Chief Data Officer	Yes	Yes	Yes	Yes	Yes
Seattle, WA	Information Technology, Police	Yes				Yes
Sunnyvale, CA	Police	Yes				
Topeka, KS	Information Technology		Yes			
Washington, DC	Information Technology	Yes	Yes		Yes	Yes
	Totals	**37**	**20**	**26**	**15**	**28**

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Many of Ho's publications were the results of engaged research, in which he worked closely with local government officials, community leaders, and foundation officers to address specific policy questions and managerial needs of local communities. Former community partners include the Iowa League of Cities; the Iowa Association of Counties; the city of Indianapolis, Indiana; the city of Tulsa, Oklahoma; the city of Kansas City, Missouri; the Johnson County Library Foundation in Kansas; the William T. Kemper Foundation in Kansas City, Missouri; the Alfred P. Sloan Foundation; the National Science Foundation; and the Asian Development Bank.

Ho is also an active member in the professional community of public administration. He has been an editorial board member for a few journals, including *American Review of Public Administration, Journal of Public Administration Research and Theory, Public Administration Review,* and *Public Performance and Management Review*. He is also an elected representative of the National Council of the American Society for Public Administration (ASPA), and he is one of the co-chairs of the "Government Efficiency, Effectiveness, and Governance" study group at the International Institute of Administrative Sciences in Brussels, Belgium.

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