Designing A Smart City Data Platform to Unlock the Power of Civic Internet of Things Technologies

Insights from the National Institute of Technology and Standards (NIST) Global City Supercluster Platform Workshop held in Kansas City, Missouri February 7-8, 2017

GLOBAL CITY TEAMS CHALLENGE

thinkBIG PARTNERS · KC · City of Bellevue · KC DIGITALDRIVE · xaqt

Preface

This white paper reflects the collective wisdom of the one hundred eighteen people who gathered in Kansas City, Missouri in early February 2017 to figure out how to transform cities into data-driven organizations focused on providing 21st Century Services to 21st Century Citizens. Our goal was – and remains – to identify the 85-120 things that all cities measure in a standardized, replicable form so that we can better partner with industry and academic institutions and solve issues. We didn't get there in two days. What we did accomplish was an identification of several considerations that cities need to account for when building the data driven culture. We also figured out that many of the challenges that we face in Kansas City are shared in large municipalities like Chicago and New York City and smaller cities like Akron, OH and Branson, MO.

We are indebted to the individuals listed Appendix 4 who participated in this effort. Everyone listed there deserves authorship credit for the consensus we achieved at the Supercluster event. We are especially indebted to Dr. Sokwoo Rhee from NIST, who envisioned this collaborative environment; Mr. Herb Sih and the team at ThinkBig Partners, who captured the lessons learned and conducted additional research to capture the scope of the data challenge with the Texas A&M Mobility Study; Mr. Aaron Deacon from KC Digital Drive, who drove the concept and agenda setting for the conference and Mr. Chris Crosby, CEO and Founder of Xaqt, who collaborated with Harvard to produce the Pothole Prediction Study.

Much work remains. At the conclusion of the August GCTC Summit in Washington DC, we will collect feedback from additional cities and thought leaders to refine what we have done. We will collect several sets of city key performance indicators and use those data sets to prepare for a 2018 activity where we can continue the work before us: to lead the next (r)evolution in urban management.

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Chief Innovation Officer, Kansas City, Missouri

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Introduction

In 2016, the United Nations reported that an estimated 54.5% of the world's population lived in urban settlements. By 2030, urban areas are projected to swell to 60% and one in every three people will live in a city. With more than three million people moving into urban areas each week, cities are faced with an unprecedented challenge. How do you deliver essential services to your citizens in the face of already stressed aging infrastructure, shrinking budgets and a myriad of challenges that create complexity never envisioned by any civil engineer prior to the 21st century based on this mass influx of people? The pace of change is daunting and cities who do not act to address this seismic migration surge will likely face dire consequences.

The smart city concept, based on internet of things (IoT) technologies wirelessly connecting infrastructure using sensors, beacons and other devices that produces substantial amounts of data, was developed to help cities gain better manage their assets. The concept of building a "smart city" can be traced back to various movements and research papers published in the late 20th century. One of the most notable early research pieces from the Los Angeles Community Analysis Bureau, "The State of the City: A Cluster Analysis of Los Angeles (1974)", "sought new tools to address the old challenges of deteriorating housing by providing detailed local data to identify neighborhoods showing early signs of obsolescence." Data was identified as one of the keys to gaining a better understanding to an urbanization problem, and that axiom holds true more than ever in 2017.

Modern daily life and the problems associated with it, defined by data, allows deeper insight and decision-making capabilities that both city officials need, and the innovation community requires, to create better solutions to deal with the urban challenges of densification. Quality data is essential, however, making the data accessible and understandable is critical to making the data ultimately valuable.

How do cities deal with the enormous amounts of data that smart cities produce? Once collected, how do city officials interface with this data to extract the right information to make effective operational and strategic decisions? How are these decisions made in a time efficient manner without sacrificing insight, relevance or the ability to synthesize multiple disparate data sources to make a single yet complex decision based on multiple real-time inputs? These are some of the challenges cities face as they deal with the

The National Institute of Standards and Technology (NIST), in support of the smart city space, created the Global City Teams Challenge (GCTC) to help cities create a more unified multi-city, multi-stakeholder conversation to deal with the complex issues associated with operating a city with the daunting urbanization challenges. The role that smart city technology can play across diverse sectors (transportation, energy, manufacturing, healthcare, etc.) can enable cities to improve services, promote economic growth and enhance the quality of life for citizens around the world. GCTC was designed to encourage collaboration among cities and help in the development of standards.

“GCTC’s long-term goal is "to establish and demonstrate replicable, scalable, and sustainable models for incubation and deployment of interoperable, standard-based solutions using advanced technologies such as IoT and CPS, and demonstrate their measurable benefits in communities and cities."

“The GCTC program is a collaborative platform for the development of smart cities and communities. It enables local governments, nonprofit organizations, academic institutions, technologists, and private corporations from all over the world to form project teams, or “action clusters,” and “SuperClusters,” to work on groundbreaking Internet of Things (IoT) applications within the smart city and community environment.”

“NIST, along with its partners, acts as a “matchmaker”—facilitating, advising, encouraging, nurturing, and publicizing the action clusters and their projects. Since the program launched in September 2014, GCTC has recruited and incubated over 160 action clusters with participation from over 150 cities and 400 companies/organizations from around the world.”

Global City Teams Challenge Supercluster Workshop on City Platform

On February 7-8, 2017, The City of Kansas City, Missouri, KC Digital Drive and Think Big Partners held the “NIST / KCMO Supercluster Platform Workshop” that attracted over 120 participants from around the world. During this two day event, participants came with a list of problems and questions associated with smart city data and the city platform that was needed to manage it. Additionally, inter and intra-departmental data management issues were also discussed to develop cross-sector understanding of the data platform required to make inter-departmental decisions in a near real-time, macro-city management basis.

The following report was compiled with these objectives in mind:

1. Archive the discussions held by participants during the event;
2. Capture the various data elements that were identified as valuable in the management, operations and strategic planning for city officials in the realm of smart city data relative to their major problems;
3. Assess some of the city platform functional requirements as identified by the participants based on proposed basic strategies to solve their problems;
4. Help define how cities will assess data;
5. Present ideas on how cities will fund, construct and sustain smart city systems over time;
6. Enhance some of the insights gained during the event with supplemental primary and secondary research; and
7. Provide additional insights for city data platform and beyond

The Urbanization Challenge That Cities Face

Cities are facing a crisis. If you ask most Mayors what they want for their cities, they will say "jobs, economic growth, a healthy vibrant and safe community that offers an inclusive high quality of life for all of its citizens." But to accomplish these things, a city must plan and manage its assets efficiently, to include it most precious asset – its people.

People are flocking to cities at a rate of three million people moving into urban areas each week. In 2016, an estimated 54.5 percent of the world's population lived in cities. By 2030, urban areas are expected to house 60% or more of all people globally and one in every three people will live in a city with at least 500,000 or more inhabitants.

Additionally, the number of megacities (defined by populations of 10 million inhabitants or more) will swell 32% from 31 to 41 by 2030. The urbanization challenges these megacities face can be even more complex to deal with if you have both a high population and a high population density city. While high populations create high stress workloads on existing city infrastructure, the high population density cities face this reality along with often being at an economic disadvantage. Cities like the Bangladeshi capital of Dhaka, have 14 million residents squeezed into an area of 125 square miles, making for a population density of 115,000 per square mile.

World's population by size class of settlement, 2016 and 2030

	2016			2030		
	Number of settlements	Population (millions)	Percentage of world population	Number of settlements	Population (millions)	Percentage of world population
Urban	..	4 034	54.5	..	5 058	60.0
10 million or more	31	500	6.8	41	730	8.7
5 to 10 million	45	308	4.2	63	434	5.2
1 to 5 million	436	861	11.6	558	1 128	13.4
500 000 to 1 million	551	380	5.1	731	509	6.0
Fewer than 500 000	..	1 985	26.8	..	2 257	26.8
Rural	..	3 371	45.5	..	3 367	40.0

The World's Cities in 2016 Data Booklet – United Nations

There is a widely accepted idea among urban core theorists that higher population densities lead to more productivity and sustainable economic growth. This is, in fact, not the case. While it is true that higher population cities often have higher GDP's, there is an imperfect if not inverse relationship between density and wealth as defined by city GDP. Cities that have larger populations spread out over larger land masses tend to fare much better than those megacities with densities like Dhaka, Mumbai, Karachi and Delhi. Without a healthy GDP, there is less tax base for cities to tap into to pay for city services. This economic strain can have a ripple effect, as the worse that a city performs in providing services, the harder it is for a city to attract and retain its inhabitants. One of the greatest economic drivers for a city is its people, and without proper support of its people a city will not rise to its greatest economic potential. The challenges that megacities with higher population densities face are very complex, and cities like this especially need to actively seek solutions to their challenges.

Since 2009, the US economy has generally improved but many cities face constrained budgets because of weak property tax revenue growth and cuts in federal and state financial aid.

United States GDP 2006 – 2017 (World Bank)

In many communities across the US, the existing infrastructure is already stressed, yet there is less money available to invest in maintenance, upgrades or replacement. Cities are faced with tough decisions on how to deploy their capital. Should deferred maintenance be done only when the most dire circumstances exist? Should routine, scheduled maintenance be done to preserve current levels of operational efficiency and extend asset life? Or should investments be made in modernization of infrastructure that can yield operational cost savings, or potentially even create revenue streams? There is no clear answer.

While cites are doing their best to manage historically well understood demands, there are also new emerging challenges that cities are facing. Problems associated with urbanization, such as power grid challenges, transportation and mobility challenges or public health are new concerns for city officials. Also, the threats against public safety from domestic terrorism and cybercrimes pose new challenges for cities to address with limited budgets. How do cities assess the worthiest capital investments? And once made, how are these investments measured for success? Much of the answer lies within data.

Global City Teams Challenge Supercluster Workshop on City Platform Insights

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The format for the event was based on small breakout groups, facilitated by a table leader. Each table compromised of various public and private sector participants and each session had a specific focus for discussion. These focus areas included:

- Analyzing your cities challenges (the problems)
- Operationalizing the data (use cases)
- Essentials for success
- Crossing Silos
- Key Performance Indicators (KPI's)
- Financing and managing for the future

Smart City Platform Insights Based on GCTC Participant Feedback

The following are observations based on the overall raw data, conversations held during the GCTC event and Think Big Partners' smart city industry expertise that helps put the feedback in context with the GCTC workshop goals of developing a framework for a city data platform. Note: It is not the goal of this white paper to make absolute recommendations or declare conclusions based on the feedback data. However, it is the goal to advance the understanding for NIST as cities are developing platforms, using data for IoT smart city deployments and are trying to make sense of a wide variety of data in real time in order to most effectively make purchasing, operational and strategic decisions.

We offer the following observations and insights accordingly.

- Cities are all trying to make sense of the enormous complexity of the smart city world. This complexity is both technology-based and urbanization-based. The sheer volumes of people and the unforeseen or unanticipated consequences is stressing budgets, decision making capacity (cycle time and decisions based on insight or prior experience) and leadership in an era of high public scrutiny fueled by the media (including social media).
- Return on investment (ROI) is top of mind for many cities. Cities are asking for proof and real-life use cases with demonstrated ROI's versus stated (advertised by manufacturers) ROI's. Historically, there were not enough installations to demand actual ROI figures in certain sectors (e.g. LED lights) but that has changed. Where applicable, cities want to see real ROI experiences when making investment decisions. Lack of relevant ROI feedback (when applicable) creates a budgeting challenge.
- Cities must collaborate across public-private stakeholders to fully utilize data, find funding mechanisms to pay for assets and develop a framework that is robust and consider the future.
- Certain municipal departments and assets seem to garner the most attention. This may be due to:
    - Historically demonstrated technologies (such as lighting, select public safety / crime, digital kiosks, Wi-Fi, surveillance, limited data analytics, limited traffic (to include parking and limited transportation), water, energy etc.) that offer ROI insight from "early adopters" which makes "fast followers" more likely to make investment decisions for smart city technologies.
    - Sectors (such as water, public safety (including advanced detection and predictive analytics), energy, airport, sewer, etc.) that have some of the most dire needs based on problems, citizen perception or infrastructure deficiencies.
    - Sectors that have federal grants associated with them (water, public safety, disaster preparedness, etc.) for smart city / IoT capital investment. This allows funds to be leveraged but also demands accountability (effectiveness) that can be obtained by data after installation.
- Cities need a roadmap that allows coordinated planning and investment across department silos. Without data, it is hard to contextualize and associate the problems with each other while still trying to measure ultimate ROI.
    - Cities need an effective internal framework for communication. Developing a basic understanding of language (to include definitions), data expectations (including collection process, shortcomings and accuracy of insights) while adhering to privacy policies, required citizen transparency and Freedom of Information requests without

compromise to public-private business partnerships or security (including cyber) considerations.

- Cities need to assess current technology systems that collect, manage and store data to make sure it is compatible with smart city requirements and capabilities.
- Cities must understand how to process, store, encrypt (where applicable) and make data accessible at the right levels (intra-department, interdepartmental and open data policies for the public). This applies to personally identifiable information (PII) and de-identified, aggregated data.
- There is not enough focus (education, knowledge and applied understanding) on how to pay for smart city deployments. Financial engineering is a major problem to be addressed and is expected to be partially addressed by the public-private partnership (P3) models.
- Cities need to have a more forward looking (progressive) view of data. Being able to move from descriptive and diagnostic data levels to predictive and prescriptive data levels is essential to ROI and maximization of data across departments.
  - Cities should share data with other peer cities to establish benchmarks, insights and share lessons learned relative to technology selection, operations, implementation, compliance, risk management and product development roadmap for enhanced future functionalities.
- Cities must examine their long-range planning and procurement processes, in order to be more responsive and reduce risks associated with prolonged business cycles.
- Cities without public Wi-Fi are asking themselves what is their role in providing this to the public. Should Wi-Fi be an amenity that is used as a foundational layer for citizen services and quality of life? Or is this an expensive investment that should only be made as a necessary component to a city's service deliver needs?
  - Note - The issue of digital inclusion came up from various GCTC participants over the course of the two-day event.
- Cities feel the need to get universities more involved but are unsure how or the role they should play. What is that education can play in the civic technology environment?
- Cities want to have developers access the data (open data policy, developer portal, etc.) but are unsure how to protect the data and what role the city has in managing the developer.
- Cities feel the need to communicate with the public about smart city decisions, especially related to data, but are unsure how to accomplish this. Some of the concerns are based on knowledge, no prior policy in the IoT realm, public sentiment and misperceptions about "big brother" and not having a long term clear strategy due to the dynamic nature of IoT and smart city environment.
- During the sessions, problems were identified by use case and segment, however specific KPI's and metrics were not widely discussed. We believe this was the function of many more basic questions existed and for many of the participants, KPI's were too far out of reach beyond the obvious, high level metrics.
- The role of citizen sourced data came up in various forms. Some of the inferences suggested that this data would come from personal devices (smart phones, tablets, etc.,) but was not clearly addressed. Cities should be cognizant to recognize the various sources of data to establish a chain of custody and verify data integrity, authenticity, quality and permissions.
- The ability for cities to overlay multiple departments (example – police where warrant has been issued for individual and housing where there is a code violation for property owner) where different data for one common citizen (360-degree citizen view) would be very helpful.

- Data integrity is important to maintain when it comes from a battery powered source (sensor) where the data quality could be compromised due to low voltage or under-voltage versus no voltage (and no bad data being produced). The ability to monitor the health of the data collection process and hardware is important.
- Unique transient citizen data (example out of town convention visitors, etc.) should not be overlooked. Example would be hotel rooms or transit from airport speeds. This data set is an important part of economic development data but may not be seen in larger resident citizen data of a city.
- The ability to identify the type and trend of KPI's based on outcomes may be as important as the KPI itself. An example of this would be in the vehicle arena. The type of KPI would be "reduction" (with decease in comparative data being the measurement) but the data attribute may be "energy" (lower energy usage) or "emissions" (lower pollution). The participants reported that they cannot even envision all the data that will become available but they seem to know what a positive trend would be by category.
- Sources of funding was tied to data collection and monetization. Understanding permissible use, value of data (and reasons for the degradation of the value of data) and ways to monetize non-standards assets (example access rights, pole rights, hanging rights, etc.) was important.
    - GCTC participants asked about benchmarks and norms for funding models. Funding obviously has a direct correlation to ROI. There was concern that they did not want to strike a "bad deal" or do something beyond the boundaries (which are dynamic and evolving).
    - Data sovereignty was identified as a "BIG" deal in non-US markets.
- The desire to seek and prefer open source data platforms was strong at the city level. Open source lends itself to interoperability and allows a large array of developers to continue to innovate on the functionalities of existing hardware and software while building for future needs.
- Automating the data collection process and using the proper data collection intervals for meaningful data was discussed. Being able to create routines that allowed human monitoring for exceptions was important.
- The sheer volume of data will require new communication and interpretation methods. There was a strong understanding that visualization should be highly customizable, with the ability to have user defined mutli-layers on demand, in addition to stored routines that produce standard data reporting.
- Predictive analytics was very important to GCTC participants, especially in the areas of crime.
    - Being able to make changes from the city platform (control inputs) was discussed in order to drive out the need for multiple systems at the city level. Being able to rely on the same platform to both collect, understand and make changes to the connected infrastructure would reduce the chance for human error. It would also provide a potential risk management process that would not allow changes to be made without verifying against the recommended norms based on reported data, if outside of acceptable thresholds that have been set.
- Being able to manipulate the data to find "hidden correlations" is important. This data mining could find hidden costs that could be squeeze out through more complex modeling based on a series of disparate data sources from a single asset.

- Cities discussed having a single starting point of contact or "one stop shop" where citizens could go to understand the data and interact with a government official to ask more questions or gain access if needed. This could serve as the front door to multiple siloed departments.
- Being able to detect data or data patter abnormalities was viewed as important. Cities could use this to find faulty collection processes or methods related to hardware / firmware or software. This could also be used to discover breakthrough innovation opportunities.
- Cities should establish "goals" for data and then create the necessary supporting data and benchmarks to support goal attainment. This could be done by department, at a macro-level for desired trend (example – reduction in ____) or on project basis for experimentation and testing.
- Cities want department leaders and technicians to be able to communicate more effectively to collaborate on seemingly disconnected issues that are actually connected. Example used was being able to reduce public health / mortality rates that are touched by ambulance. Reductions in notification of emergency, transit to scene and transit to hospital may all be touched by various infrastructure components that data could reveal improvement opportunities. Weather, traffic, wayfinding, signal light synchronization and more all play a role but this data may exist in different departments. Leaders and technicians should look for opportunities to connect the data streams to make better, more simplified complex decisions in shorter amounts of time with better accuracy.
- Cities discussed that the term "smart city" may need to be framed and re-framed periodically with its citizens. Data can play a storytelling role to help explain the problems while also showing progress towards improvement.
- It was discussed that cities need to use a rolling planning cycle (suggested 5 year) that allows continual refresh of goals, knowledge and technology capabilities assessment versus budgeting and prioritization needs of the city. Very important to maintain KPI's relevant to each deployment even if the technology is no longer a core focus. Historical initiative still need to be measured and reported on, especially in the case of grants.
    - It was discussed that weighted scores may be used. These scores may need to be rebalanced from time to time.
- Implementation and education were additional challenges that need to be address. In order for a smart city deployment to be successful, education for line workers and staff members is needed. Implementation of both processes and data usage need to be addressed and education is critical.
- Cities discussed leveraging large IT companies for expertise as part of diligence and design-build process. Cross department consulting services could be done by external companies and internally by city stakeholders.
- Cyber-security was a recurring underlying theme for all cities as it pertains to data, control of devices and the actual operations of various assets. Cities may look to state and federal agencies for help with process improvements and risk management.
    - Cities discussed the need to collaborate with other cities to stay ahead of threats, especially for targets that were extremely high risk or vulnerable (transportation, water supply, public health, etc.)
- Cities need to be able to connect smart city investment with the entire citizen population (inclusiveness) and also economic development. Specialized data interpretation may be need to make indirect correlations.

Looking Beyond Today's Smart City Deployment

According to McKinsey & Company, the value of Internet of things technologies in the smart city environment is worth between $930 billion to $1.7 trillion per year in 2025. The impact is staggering and much of the projected ROI is based on effective data collection, management, processing, interpretation and timely application in the field. With less than 1% of the data available being currently used, the opportunity to make quantum leaps is enormous. Those organizations that incorporate interoperability into their existing systems obtain 40% more value. Additionally, the industrial use case for data is 200% more valuable than in the consumer markets. Clearly cities must unlock the value of data beyond the hype.

Additional considerations:

- 3 out of 4 organizations that are either constrained by legacy, culture or regulatory issues simply lack the understanding of the value of data. Education, acceptance of new policies and adherence is essential for city's success.
- KPI's must be established within the boundaries of current instrumentation and monitoring.

- Scalability and heterogeneity of data are two big challenges cities will face as the IoT data exhaust becomes bigger.
- Visualization will be increasingly relied upon for final or near final analysis. Care must be given to make sure technicians do not misinterpret data due to the ease of tis interface.
- Visualizing increasingly large data sets will require new approaches for viewing and making sense of the data. The city platform must be flexible enough to grow but stable enough to allow rollback changes if needed.
- Tool kits for creating high-performance web-based data visualization will be created. Data sets must be flexible enough to allow this type of development. Outputs such as histograms, scatterplots and more will become standard output methods. Data visualization will be on multiple platforms and need to be accessible on all types of mobile devices and interfaces, to include AI platforms, voice controlled platforms and more.
- Machine learning models will play an increasingly larger role with the data being created.

Appendix 1: Bellevue Smart City Portal Approach

OVERVIEW

Cities, nationally and globally, are embarking on smart city efforts to harness the benefits of rapidly emerging technologies to improve quality of life, increase operational efficiency, enhance economic vitality and improve sustainability. Bellevue particularly benefits from its high-tech economy with companies advancing many of these capabilities, residents who take advantage of new technology and a talented workforce that expects its city to effectively benefit from technology. A smart city leverages advances in sensors, devices controllers and instruments that are connected to the internet and to other systems — essentially the Internet of Things (IoT) technologies — to produce data that can be analyzed to inform decisions, improve services and optimize operations. Advances in analytics and machine learning will support the city in moving from reactive to proactive and eventually to predictive operations.

CITY OF BELLEVUE BACKGROUND

Bellevue is the fifth largest city in Washington, with an estimated population of 140,700 (April 2017, Washington State's Office of Financial Management). Bellevue is the high-tech and retail center of the greater Seattle metropolitan area, with more than 150,000 jobs and a downtown skyline of gleaming high-rises.

With beautiful parks, top schools and a vibrant economy, Bellevue is routinely ranked among the best mid-sized cities in the United States (Livability.com and 24/7 Wall Street).

While business booms downtown, much of Bellevue retains a small-town feel, with thriving, woodsy neighborhoods and a vast network of trails. With nearly 100 parks, Bellevue is known as "a city in a park." The city's crime rates are consistently low.

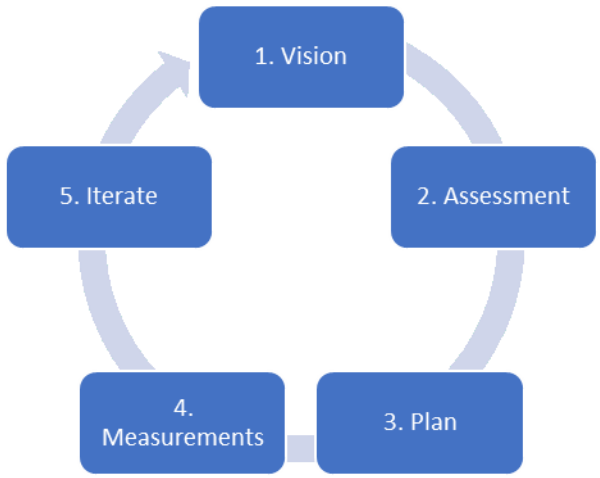
The city spans more than 33 square miles between Lake Washington and Lake Sammamish, and is a short drive from the Cascade Mountains. People can kayak within sight of downtown in the Mercer Slough Nature Park, a 320-acre wetland preserve.

The population is growing and becoming more diverse. In 2015, according to the U.S. Census, Bellevue's population became evenly split between non-Hispanic whites and people of color, making the city one of the most diverse in Washington state.

BELLEVUE'S SMART CITY APPROACH

A smart city vision figured prominently in the City Council's *Bellevue 2035 — The City Where You Want to Be* supporting the Council and Community goal of creating a High Quality Built Environment. The council also established a path to realizing this longer-term goal by focusing priorities within the two-year budget cycle. In 2014, the priority to develop the Smart City strategy to include high-speed data options to support business and residents and determine implementation steps set this plan in motion.

Bellevue's journey to becoming a smarter city took a couple years of learning and aligning the *Bellevue Smart Plan* to meet the needs of the community it serves. The process followed five major steps outlined below.



Step 1: Start with a Vision

Bellevue is a "smart city" with a clean, high-quality environment and excellent and reliable infrastructure that supports our vibrant and growing city, including high-tech connectivity. The city has a connected multi-modal transportation system, which blends seamlessly with its buildings, plazas and parks.

To achieve the City Council's vision for a smart city, the initial focus was to evaluate emerging and innovative technologies to gain a clearer picture of what "smart city" could be and to discover the potential for these technologies to best address Bellevue's needs. Bellevue's smart city approach also tailors focus areas to the priorities articulated in the community vision as captured in the Comprehensive Plan. Desired outcomes were defined that describes end results of a smart city effort and the benefits to the community.

- **Livability**: Smart technologies improve the safety, health, convenience and quality of life for the community, while increasing our economic competitiveness.
- **Sustainability**: The city delivers excellent, long-term services by reducing waste, increasing efficiencies and protecting the environment.
- **Resiliency**: The city is able to respond more effectively to emergencies and recover faster from disruptive events.

Six elements were then identified that best align with the community and council vision. These elements provide a structure that focuses efforts, clarifies objectives and helps organize strategies.

<table>
<tr>
<td>CONNECTIVITY
Increasing communication network speed, capacity and availability

Improve consumer services and communications infrastructure, through an emphasis on increasing high-speed communications:
▪ Expand Wi-Fi to reduce digital divide
▪ Grow fiber-optic network
▪ Increase high-speed broadband availability
▪ Integrate smart city networks to increase efficiencies and monitor emerging capabilities
▪ Provide improved citizen-information access</td>
<td>TRANSPORTATION
Moving people smarter, safer and faster, while providing more choices, better real-time information, lowering emissions and raising efficiencies

Improve ways for people to move around the city:
▪ Enhance adaptive traffic signal operations
▪ Improve traveler information
▪ Integrate multi-modal travel options to improve mobility
▪ Advance Vision Zero to provide safer mobility for vehicles, pedestrians and bike riders</td>
<td>PUBLIC SAFETY
Reducing response time, increasing survival rate, reducing crime rate, increasing emergency capabilities

Further integrate infrastructure, services, agencies, and personnel that cities call on to keep people safe:
▪ Improve 911 services
▪ Enhance communications networks for greater interoperability and backup
▪ Increase incident situational awareness for effective response
▪ Enhance data-driven policing practices
▪ Improve hazmat awareness and mitigation</td>
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<tr>
<td>WATER
Delivering high-quality and reliable water, protecting critical infrastructure, conserving resources

Ensure high-quality delivery of water services to homes and businesses to minimize disruptions and increase customer service:
▪ Integrated asset management to improve efficiencies
▪ Smart system operations
▪ Advanced metering allows frequent readings, leak detection and increases customer awareness of options</td>
<td>BUILDINGS
Optimizing building performance, decreasing wasted energy and water, increasing comfort and safety

Enhance building systems and analytics to improve building systems performance and resource conservation and efficiencies:
▪ Building energy data benchmarked to influence conservation/resource savings
▪ Building water data benchmarked to influence conservation/resource savings</td>
<td>ENERGY
Improving grid reliability, increasing efficiency, connecting renewables

Improve and integrate energy systems to ensure sufficient, efficient and reliable energy that power all systems our modern digital society requires:
▪ Implement smart grid system operations for increased reliability
▪ Energy conservation and efficiency and increase in renewables
▪ Two-way automated metering increases communication with energy partners like PSE</td>
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Step 2. Conduct an Assessment

To define strategies for each smart city element, it was important to start by asking: “How smart is the city right now?” By understanding the current state, a more informed approach for each element could be tailored to address its distinct needs and achieve the overall objectives. A maturity assessment tool was developed to define gaps and shape strategies. Maturity levels were defined from basic services at the Ad-hoc level 1 to the highest capabilities of Optimized level 5. At the highest level, services and systems are proactive, real-time adaptive, resilient and interoperable, establishing an ideal long-term, end-state for each element.

The overall maturity assessment results are below, with solid filled boxes representing where Bellevue is today. Aspirations for the next three to five years are represented by hashed arrows. The intent is to pragmatically move towards the managed and optimized states to achieve increasing capabilities.

These levels and gaps guided the development of strategies, including budget proposals and other funding possibilities. Elements were broken down into corresponding sub-elements.

Maturity Index	1	2	3	4	5
Standard Scale	Ad-hoc	Opportunistic	Repeatable	Managed	Optimized
CONNECTIVITY					
TRANSPORTATION					
PUBLIC SAFETY					
WATER					
BUILDINGS					
ENERGY					

Step 3. Develop a Plan

The smart city plan is centered on four Principal Strategies that apply across all the elements. All elements deploy these common strategies, albeit with appropriate variations, in order to accomplish the objectives of that element.

Focus on proactive and adaptive. A smart city shifts from reactive mode, responding when a problem is reported, to a proactive, even predictive, mode able to anticipate and adapt in real-time to changing conditions. In order to be proactive and adaptive, systems must be integrated and interoperable to achieve the greatest benefits in safety, service and convenience. Systems also need to be designed for high levels of reliability and resiliency because of the low tolerance for disruption and cascading impacts if critical systems do not function properly.

Drive with data. The proliferation of smart devices like controllers, sensors, devices and vehicles connected to the internet, produce enormous amounts of data that enable a smart city to improve operations, services and infrastructure. Embedded machine learning and artificial intelligence can also enhance automation and drive efficiencies of systems and enhance staff productivity. Increasing competency by using data effectively to drive decision making is necessary. Without this increase in competency, the volume and velocity of data streaming from smart systems will overwhelm the city's ability to turn data into meaningful and useful information.

Pursue partnerships. The impact of IoT on city infrastructure systems, community homes and buildings, vehicles on city roads and real-time information expectations is challenging the city's normal, forward-thinking approach to technology adoption. Fortunately, Bellevue's high-tech region, with an abundance of technology innovators, opens up partnership opportunities to help shape industries, services and technologies that can keep Bellevue in the forefront of innovation. The city already sustains an entrepreneurial and talented workforce with many innovative startups.

This community influences how the city pursues technology to meet service expectations and fulfill the community's vision. Bellevue has been and will continue to be a testbed for pilot projects.

Leverage regional relationships. Ultimate goals, like clean water and a safe community, require relationships and interactions that extend well beyond Bellevue's boundaries. Crime and congestion does not stop at the city's borders, and regional solutions should be leveraged. Bellevue has a solid history of being a regional collaborator. The city provides services to other cities, like water utilities; receives services from other organizations, such as 911 service; and relies on mutual aid agreements with other agencies in the case of fire services. Systems like roads, water, energy and fiber optic networks also cross city boundaries.

Step 4. Identify Measurements

The city uses performance management to monitor effectiveness and efficiency of city services. The following measures and indicators track progress on accomplishing the objectives within each smart city element. In some instances, measures signify the city's direct impact on objectives, such as traffic collision measures related to safety goals. Other indicators more loosely gauge the city's ability to influence or facilitate more wide-ranging outcomes, such as broadband adoption rate and availability of competition for consumer internet services that can also be shaped by other factors. Measures will be continually re-evaluated as new systems bring advancements and additional data can be used to improve measures.

CONNECTIVITY • Broadband adoption rate indicating availability of competition for consumer services • Smartphone ownership rate as indicator of increasing connectivity demand • Free-access Wi-Fi access points within the community	**TRANSPORTATION** • Number of fatal and serious injury collisions to quantify road safety and attainment of Vision Zero goals • Miles of designated bike paths/lanes, supporting availability of multimodal transportation choices • Single-occupant vehicle rate reflecting effectiveness of transportation choices	**PUBLIC SAFETY** • Patrol response time to life-threatening emergencies • Violent crimes and property crimes rate as a measure of community safety • Percentage of fire response time in six minutes or less, from call to arrival • Cardiac arrest survival rate as an effectiveness measure of emergency medical services
WATER • Regulatory compliance monitoring drinking water quality • Unplanned water service interruptions avoided due to leak detection • Wastewater overflows mitigated due to SCADA warnings	**BUILDINGS** • Number of Energy Star-rated buildings in Bellevue as indicator of smart building efficiencies in the community • Median energy use for municipal buildings achieved through the adoption of smart building systems/practices	**ENERGY** • Residential, commercial, industrial energy, as indicators of efficiencies from conservation practices and systems, such as advanced metering • Frequency of electrical service interruptions • Duration of interruptions to monitor impacts to customers

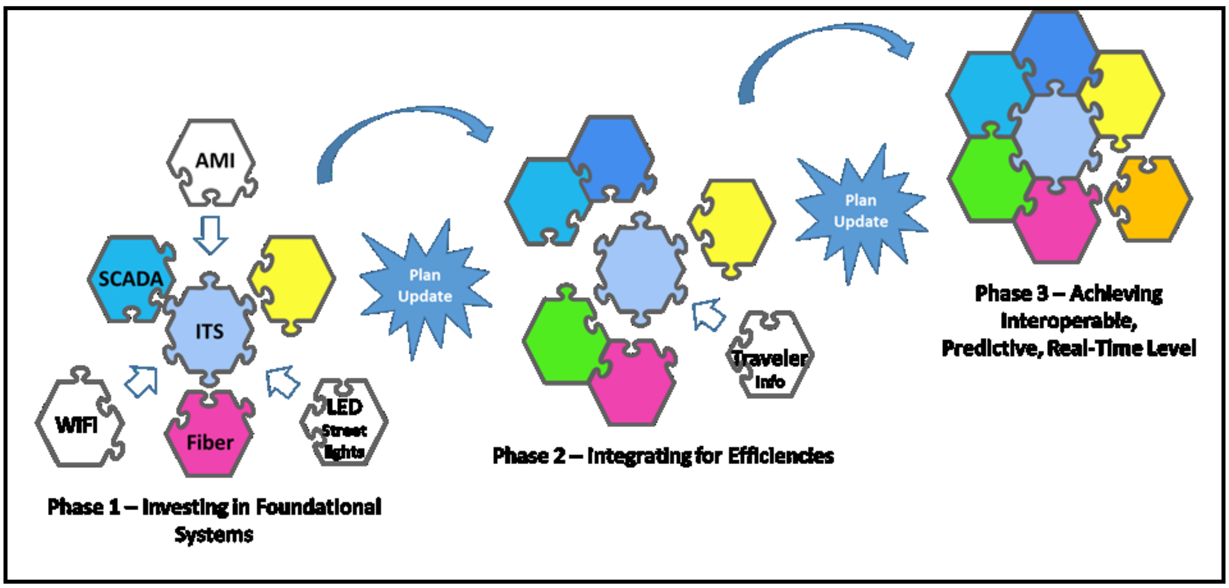
Step 5. Iterate

Due to the complexity of integrating systems and adopting emerging technologies, becoming a smarter city will take longer than a year or a single budget cycle, and must be done in a phased iterative approach that allows for planning of major projects while building in enough flexibility to take advantage of opportunities that arise or adjust tactics based on rapid changes.

At least three phases are envisioned in the ***Bellevue Smart: Planning for a Smarter City***.

1. Phase 1 – Investing in Foundational Systems
2. Phase 2 – Integrating for Efficiencies
3. Phase 3 – Achieving Proactive, Real-time Adaptive, Resilient and Interoperable Capabilities

The current version of the smart city plan focuses on Phase 1, where major investments are being made in critical systems and plans, such as Advanced Metering, the Intelligent Transportation System Master Plan Update and others. Some system and data integration efforts are already underway for increased levels of service. Phase 2 of this plan will build on those efforts. During Phase 3, the city achieves hoped-for levels of services and system capabilities, but can accelerate tactics depending on emerging capabilities and partnership opportunities that might arise.



SMART CITY PORTAL

Developing a Smart City Portal follows the same process as developing a smart city plan.

1. **Vision**. To reap the benefits of smart city systems, making data visible to staff and the public is critical. Preferably information is easy to understand and map-based.
2. **Assessment**. Bellevue already has many systems producing data. The smart city elements help provide a framework for what data to make available on the portal.
3. **Plan**. NIST's Replicable Smart City Technologies grant program provided an opportunity to kick start a portal development effort. As part of the grant proposal process, a plan was developed with City of Bellevue and CH2M.
4. **Measurements**. As part of the grant, regular progress reports on schedule, progress and financial are submitted. Also, the

5. **Iterate**. While a full portal was envisioned that includes all elements, a starting point was needed as a foundation. The Water module was selected as an appropriate first iteration.

NIST Grant and Progress to Date

One of the foundational investments the City has undertaken is the creation of a Smart City Portal. In 2016, the applied for and received a $75,000 grant, and become one of four smart cities initiatives to receive a total of $350,000 in funding from the National Institute of Standards and Technology (NIST).

Bellevue partnered with NIST, CH2M, and Quantela to develop and pilot the technologies needed to make better use of its existing water system data, gather new data, and effectively share real-time data across departments. The City of Bellevue's Smart City approach will result in reduced costs and greater effectiveness and efficiencies in operating individual departments, enhancing customer service, and communicating across departments. Development of a visual, GIS-based dashboard (the City Portal) to display this data will enhance the daily activities of both City staff and residents.

Early in the development of the NIST project, the Bellevue Smart team made the decision to focus efforts on developing the first module of the City Portal, the Water Module, which will provide the foundation for continued Smart City development as the City integrates additional modules and future technology advancements. The Water Module will draw real-time data from the City's water utility operations, including online water quality monitoring (OWQM) data, compliance testing results, and other related key parameters. Once evaluated and accepted by key stakeholders, the Water Module will serve as the basis for development of additional modules for other City departments.

Going forward, the team will work to develop data analytics and improve interconnectivity of department systems City-wide, including Police and Fire, Civic Services, Transportation, Utilities, Environmental, and Information Technology (IT). The goal of the Bellevue Smart City Program is to enable all City staff, citizens, and visitors to leverage different levels of real-time data from throughout the city for use in their daily activities.

As a NIST-funded project, broader goals include ensuring the solution is replicable and scalable for any city, is based on a well-documented open architecture, employs industry standards, and is designed for modularity.

Appendix 2: The Challenges of Data - A Texas A&M Case Study (Mobility)

Data can help create a measurable return on investment (ROI) by providing a city real time insight into an infrastructure operating condition and allow some type of action to take place that would have otherwise not occurred. Cities must assess the value of the data collected by the value of the insight gained or corrective action achieved. This may seem like a straightforward proposition, but there are many moving parts to consider. Here are just a few considerations:

- What data is useful?
- Under what conditions is the data useful?
- What are the steps both necessary and feasible to obtain the data?
- Who needs the data?
- When do different parties need access to this data?
- In what forms (tabular, visual, etc.) is the data useful?
- How will the data be used?

To further examine the role of data and the complex nature of quality data collection, let's examine traffic (congestion in urban areas).

Traffic is a particularly insightful; proxy for the overall complexity of data in the Smart City ecosystem. Traffic data brings in moving and stationary objects, human and inanimate objects and is highly dynamic due to ever changing weather conditions, construction, road conditions based on infrastructure conditions, events that draw substantial amounts of people and other complex but highly associated factors. Traffic also must be presented in multiple platforms in real time to be useful to all stakeholders. Traffic also has a high degree of sensitivity and importance depending on the user, their location, time of day, weather conditions, transportation method and reason for mobility.

The U.S. national average time spent in congestion reached 42 hours last year as metropolitan areas continue to grow. Increases in population, productivity and employment, coupled with low fuel costs, continue to put pressure on already-stressed urban freeways and arterials. Americans drove over 3.2 trillion miles on roads last year – a three percent boost over the prior year and an all-time high. As vehicle miles-traveled continues to grow, decision makers are pressed to find the most effective solutions with limited budgets.

City officials, transportation experts and the public all seem to agree that there is no single performance indicator that captures all insight definitively.

The Texas A&M Transportation Institute helped create the Urban Mobility Scorecard. Findings in the *2015 Urban Mobility Scorecard* are drawn from traffic speed data collected by INRIX on 1.3 million miles of urban streets and highways, along with highway performance data from the Federal Highway Administration. This 2015 report provides a comprehensive analysis of traffic conditions in 471 urban areas across the United States. The vast amount of information makes it possible to examine problems in greater detail than before, and to identify the effect of solutions at specific locations.

The following steps were used to calculate the congestion performance measures for each urban roadway section.

1. Obtain Highway Performance Monitoring System (HPMS) traffic volume data by road section
2. Match the HPMS road network sections with the INRIX traffic speed dataset road sections

3. Estimate traffic volumes for each hour time interval from the daily volume data
4. Calculate average travel speed and total delay for each hour interval
5. Establish free-flow (i.e., low volume) travel speed
6. Calculate congestion performance measures
7. Additional steps when volume data had no speed data match

The 2015 Urban Mobility Scorecard required four primary data inputs:

- Actual travel speed
- Free-flow travel speed
- Vehicle volume
- Vehicle occupancy (persons per vehicle) to calculate person-hours of travel delay

It is worth noting that the INRIX Research team created the INRIX Traffic Scorecard. Their work and comprehensive study created a transportation metric, the INRIX Congestion Index, which provides transportation agencies a fresh perspective on the health of a transportation network; an average congestion rate measures the impact of congestion on a typical driver's trip; and the peak hour spent in congestion metric gives auto commuters insight on their drive to and from work.

Based on this data collection process, the following information is provided based on the 2015 report to show the complex nature of smart city data collection and the corresponding outputs:

Step 1. Identify Traffic Volume Data

The HPMS dataset from FHWA provided the source for traffic volume data, although the geographic designations in the HPMS dataset are not identical to the INRIX speed data. The daily traffic volume data must be divided into the same time interval as the traffic speed data (hour intervals). While there are some detailed traffic counts on major roads, the most widespread and consistent traffic counts available are average daily traffic (ADT) counts. The hourly traffic volumes for each section, therefore, were estimated from these ADT counts using typical time-of-day traffic volume profiles developed from continuous count locations or other data sources. The section "Estimation of Hourly Traffic Volumes" shows the average hourly volume profiles used in the measure calculations.

Volume estimates for each day of the week (to match the speed database) were created from the average volume data using the factors in Exhibit A-1. Automated traffic recorders from around the country were reviewed and the factors in Exhibit A-1 are a "best-fit" average for both freeways and major streets. Creating an hourly volume to be used with the traffic speed values, then, is a process of multiplying the annual average by the daily factor and by the hourly factor.

Exhibit A-1. Day of Week Volume Conversion Factors

Day of Week	Adjustment Factor (to convert average annual volume into day of week volume)
Monday to Thursday	+5%
Friday	+10%
Saturday	-10%
Sunday	-20%

Step 2. Combine the Road Networks for Traffic Volume and Speed Data

The second step was to combine the road networks for the traffic volume and speed data sources, such that an estimate of traffic speed and traffic volume was available for each roadway segment in each urban area. The combination (also known as conflation) of the traffic volume and traffic speed networks was accomplished using Geographic Information Systems (GIS) tools. The INRIX speed network was chosen as the base network; an ADT count from the HPMS network was applied to each segment of roadway in the speed network. The traffic count and speed data for each roadway segment were then combined into areawide performance measures.

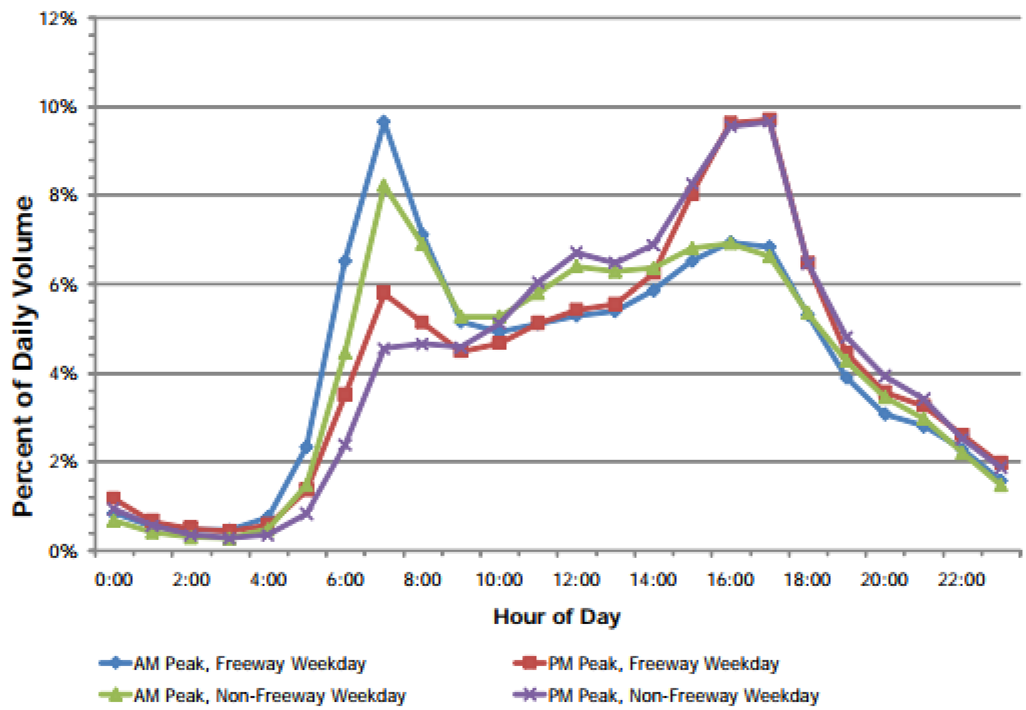
Step 3. Estimate Traffic Volumes for Shorter Time Intervals

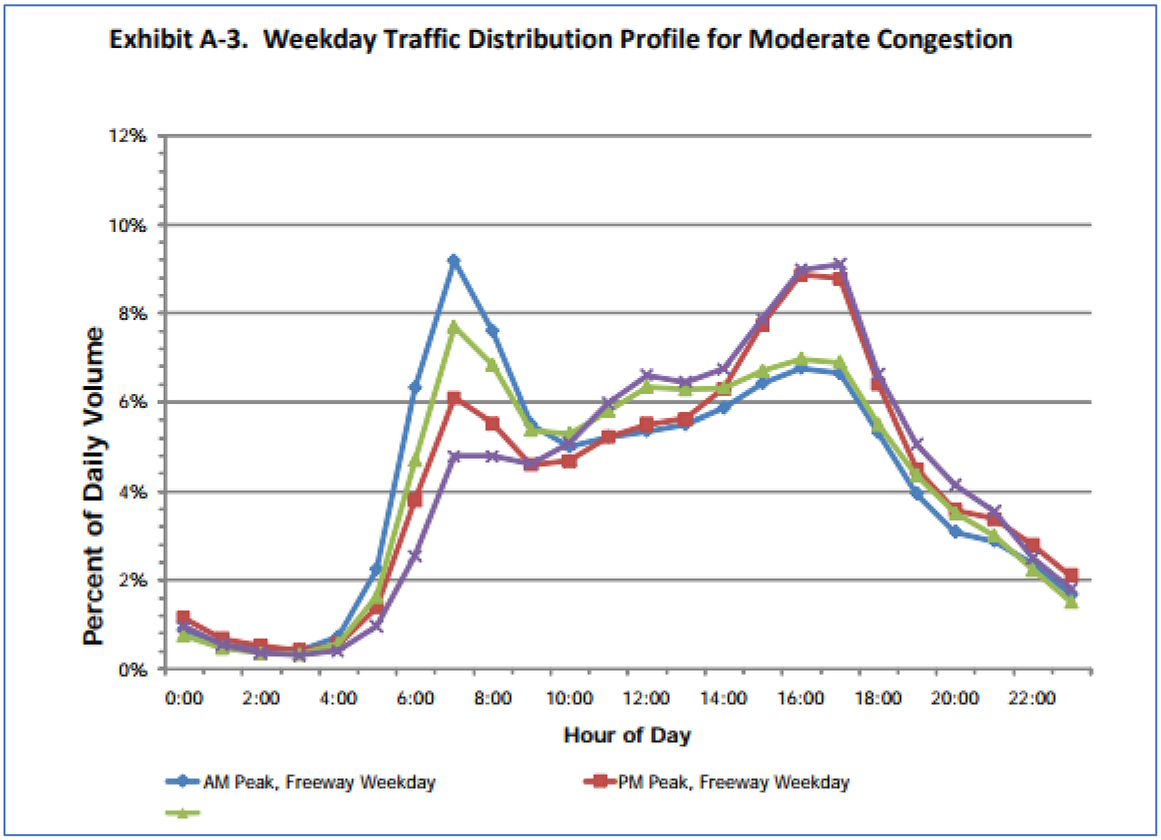
The third step was to estimate traffic volumes for 15-minute time intervals for each day of the week to match with the time aggregation of the speed data. Typical time-of-day traffic distribution profiles are needed to estimate hourly traffic flows from average daily traffic volumes. Previous analytical efforts1,2 have developed typical traffic profiles at the hourly level (the roadway traffic and inventory databases are used for a variety of traffic and economic studies). These traffic distribution profiles were developed for the following different scenarios (resulting in 16 unique profiles):

- Functional class: freeway and non-freeway
- Day type: weekday and weekend
- Traffic congestion level: percentage reduction in speed from free-flow (varies for freeways and streets)
- Directionality: peak traffic in the morning (AM), peak traffic in the evening (PM), approximately equal traffic in each peak

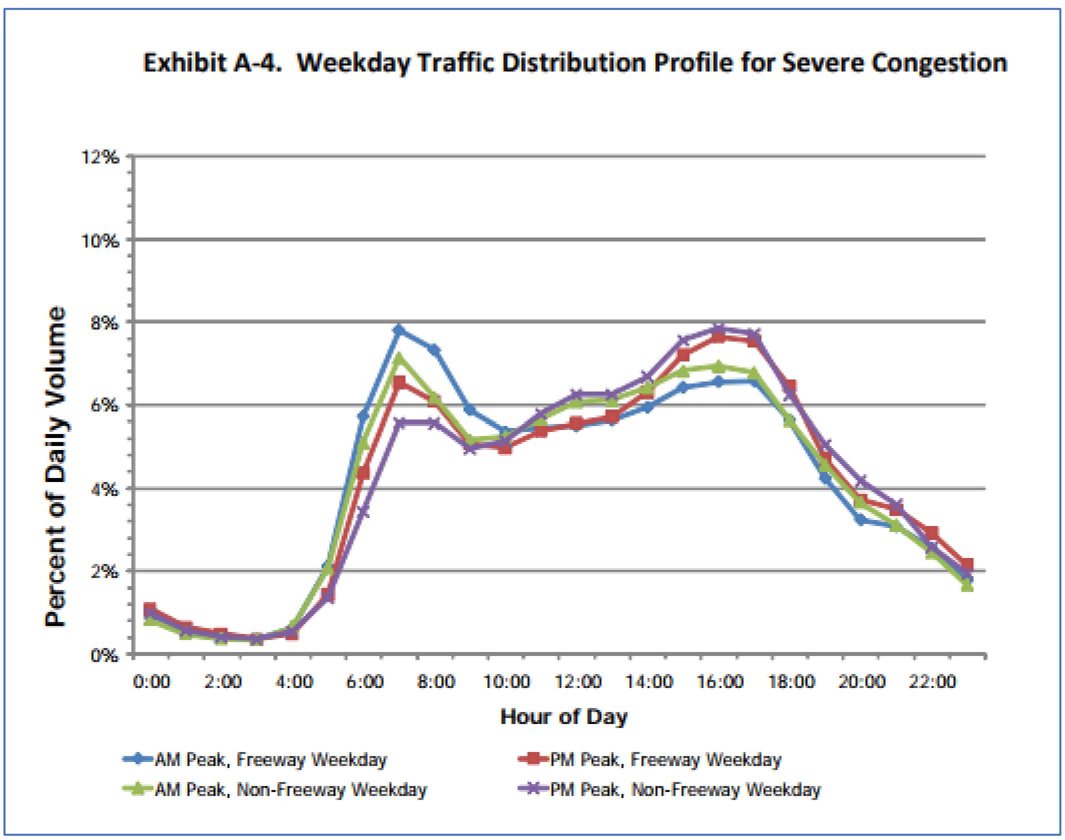
The 16 traffic distribution profiles shown in Exhibits A-2 through A-6 are considered to be very comprehensive, as they were developed from 713 continuous traffic monitoring locations in urban areas of 37 states.

Exhibit A-2. Weekday Traffic Distribution Profile for No to Low Congestion

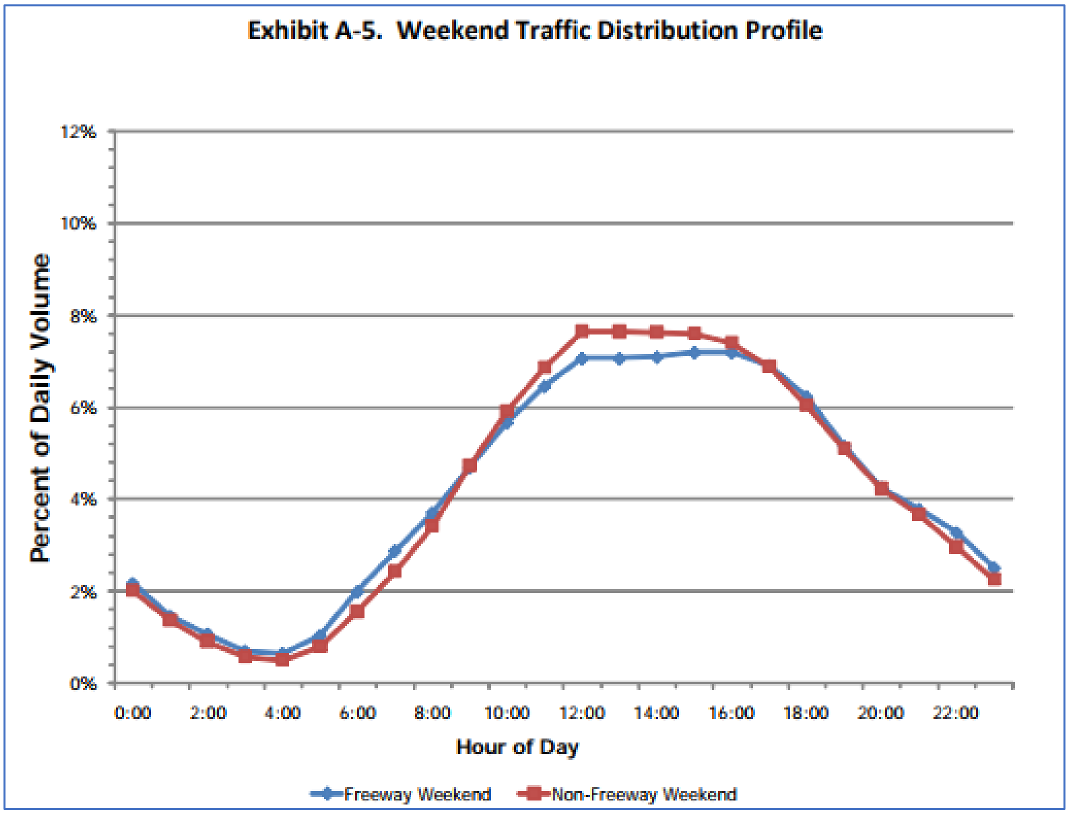




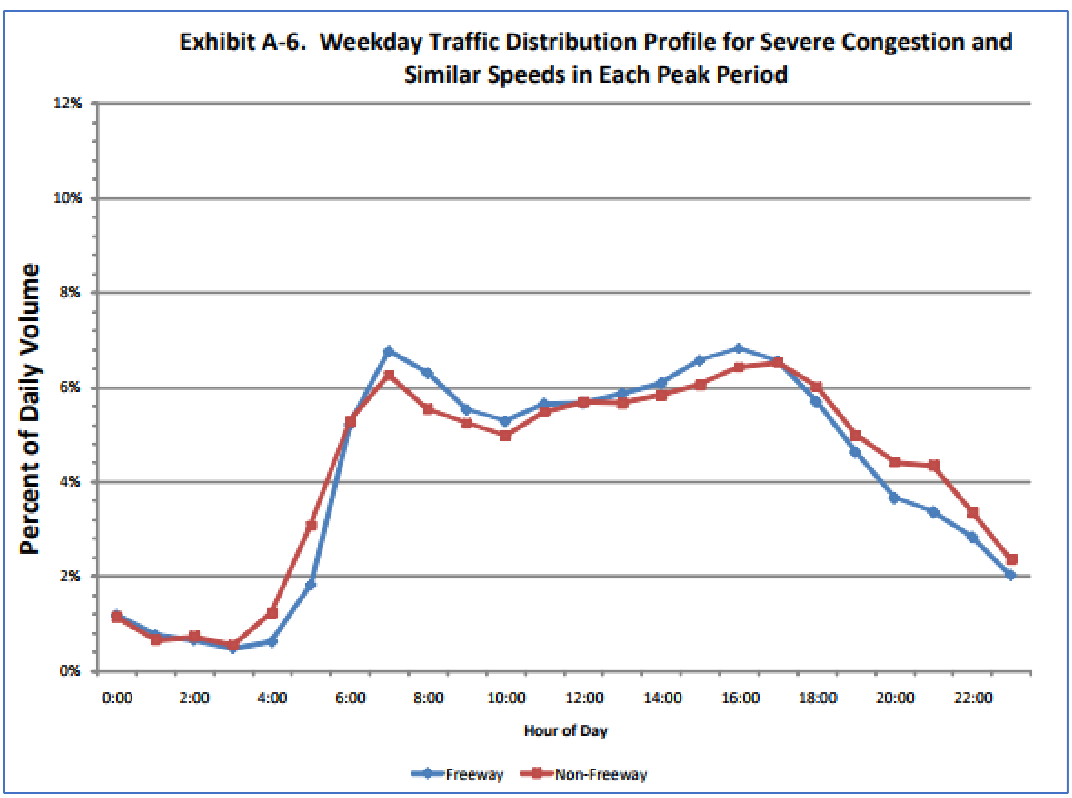
2015 Urban Mobility Scorecard Methodology



2015 Urban Mobility Scorecard Methodology



2015 Urban Mobility Scorecard Methodology



2015 Urban Mobility Scorecard Methodology

The next step in the traffic flow assignment process is to determine which of the 16 traffic distribution profiles should be assigned to each XD Network roadway link ("XD Network" is the "geography" used by INRIX to define the roadways), such that the hourly traffic flows can be calculated from traffic count data supplied by HPMS. The assignment should be as follows:

Functional class: assign based on HPMS functional road class

- Freeway – access-controlled highways
- Non-freeway – all other major roads and streets

Day type: assign volume profile based on each day

- Weekday (Monday through Friday)
- Weekend (Saturday and Sunday)

Traffic congestion level: assign based on the peak period speed reduction percentage calculated from the private sector speed data. The peak period speed reduction is calculated as follows:

1. Calculate a simple average peak period speed (add up all the morning and evening peak period speeds and divide the total by the 8 periods in the eight peak hours) for each XD Network
2. Calculate a free-flow speed during the light traffic hours (e.g., 10 p.m. to 5 a.m.) to be used as the baseline for congestion calculations.
3. Calculate the peak period speed reduction by dividing the average combined peak period speed by the free-flow speed

$$\text{Speed Reduction Factor} = \frac{\text{Average Peak Period Speed}}{\text{Free-Flow Speed (10 p.m. to 5 a.m.)}}$$

2015 Urban Mobility Scorecard Methodology

For Freeways:

- Speed reduction factor ranging from 90% to 100% (no to low congestion)
- Speed reduction factor ranging from 75% to 90% (moderate congestion)
- Speed reduction factor less than 75% (severe congestion)

For Non-Freeways

- Speed reduction factor ranging from 80% to 100% (no to low congestion)
- Speed reduction factor ranging from 65% to 80% (moderate congestion)
- Speed reduction factor less than 65% (severe congestion)

Directionality: Assign this factor based on peak period speed differentials in the private sector speed dataset. The peak period speed differential is calculated as follows:

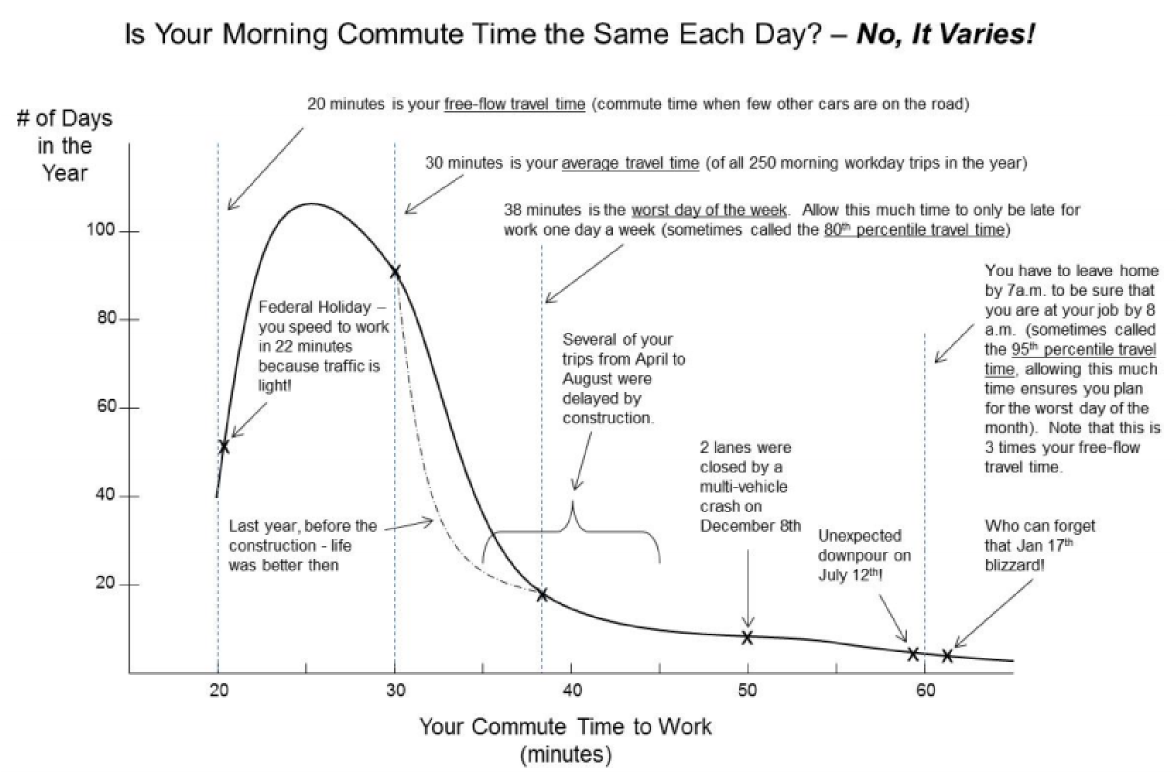
1) Calculate the average morning peak period speed (6 a.m. to 10 a.m.) and the average evening peak period speed (3 p.m. to 7 p.m.)

2) Assign the peak period volume curve based on the speed differential. The lowest speed determines the peak direction. Any section where the difference in the morning and evening peak period speeds is 6 mph or less will be assigned the even volume distribution.

For brevity sake, we will not show additional data collection processes or raw data graphs from the 2015 Urban Mobility Scorecard, but it is worth noting that “Truck-Only Volume Profiles” was another specific output. Again, there are many users to consider, and as smart city data becomes more prevalent, trusted and sophisticated, so will the use cases and the demands to collect this data will become more complex.

The following is a composite graph that was created to make visualization of the 2015 Urban Mobility Scorecard more accessible:

Exhibit A-11. Example of Morning Commute Travel Time Distribution



2015 Urban Mobility Scorecard Methodology

Data Collection, Reporting and Communication in The Public Domain

The Texas A&M Transportation Institute is the largest university-affiliated transportation research agency in the U.S. and a member of the Texas A&M University System. Since 1950, the Institute has been dedicated to saving lives, time, and resources by addressing problems related to all modes of transportation. This agency and its work is a good model to examine to help aid in the development of a smart city data platform, data collection processes and data communication (tabular and visual representation, analysis and general public communication to various stakeholders).

The Texas A&M Transportation Institute illustrates some of the complexity that went into collecting the right information to create the right insight and ultimate ROI. The following are some of the performance measures and definition of terms that were used:

- Travel Time Index – A measure of congestion that focuses on each trip and each mile of travel. It is calculated as the ratio of travel time in the peak period to travel time in free-flow. A value of 1.30 indicates that a 20-minute free-flow trip takes 26 minutes in the peak.
- Planning Time Index – A travel time reliability measure that represents the total travel time that should be planned for a trip. Computed with the 95th percentile travel time it represents the amount of time that should be planned for a commute trip to be late for only 1 day a month. If it is computed with the 80th percentile travel time it represents the amount of time that should be planned for a trip to be late for only 1 day a week. A PTI of 2.00 means that for a 20-minute trip in light traffic, 40 minutes should be planned.
- Peak Commuters – Number of travelers who begin a trip during the morning or evening peak travel periods (6 to 10 a.m. and 3 to 7 p.m.). "Commuters" are private vehicle users unless specifically noted.
- Annual Delay per Commuter – A yearly sum of all the per-trip delays for those persons who travel in the peak period (6 to 10 a.m. and 3 to 7 p.m.). This measure illustrates the effect of traffic slowdowns as well as the length of each trip.
- Total Delay – The overall size of the congestion problem. Measured by the total travel time above that needed to complete a trip at free-flow speeds. The ranking of total delay usually follows the population ranking (larger regions usually have more delay).
- Free-Flow Speeds – These values are derived from overnight speeds in the INRIX speed database. They are used as the national comparison thresholds. Other speed thresholds may be appropriate for urban project evaluations or sub-region studies.
- Excess Fuel Consumed – Increased fuel consumption due to travel in congested conditions rather than free flow conditions.
- Congestion Cost – Value of travel delay for 2014 (estimated at $17.67 per hour of person travel and $94.04 per hour of truck time) and excess fuel consumption estimated using state average cost per gallon.
- Urban Area – The developed area (population density more than 1,000 persons per square mile) within a metropolitan region. The urban area boundaries change frequently (every year for most growing areas), so increases include both new growth and development that was previously in areas designated as rural.
- Number of Rush Hours – Time when the road system might have congestion.

National Tabular Data

The Mobility Data for All 471 Areas - Averages

Inventory Measures	2014	2013	2012	2011	2010
Urban Area Information					
Population (1000s)	486	483	481	478	473
Rank	--	--	--	--	--
Commuters (1000s)	233	233	233	232	232
Daily Vehicle-Miles of Travel (1000s)					
Freeway	4,076	4,045	3,992	3,938	3,883
Arterial Streets	4,384	4,342	4,299	4,253	4,214
Cost Components					
Value of Time ($/hour)	17.67	17.39	17.14	16.79	16.30
Commercial Cost ($/hour)	94.04	89.60	89.56	86.81	88.12
Gasoline ($/gallon)	3.20	3.51	3.30	3.40	2.75
Diesel ($/gallon)	3.50	3.90	3.65	3.75	3.01
System Performance	**2014**	**2013**	**2012**	**2011**	**2010**
Congested Travel (% of peak VMT)	32	--	--	--	--
Congested System (% of lane-miles)	25	--	--	--	--
Congested Time (number of "Rush Hours")	4.39	--	--	--	--
Annual Excess Fuel Consumed					
Total Fuel (1000 gallons)	6,629	6,526	6,418	6,124	6,053
Rank	--	--	--	--	--
Fuel per Peak Auto Commuter (gallons)	19	19	18	18	18
Rank	--	--	--	--	--
Annual Delay					
Total Delay (1000s of person-hours)	14,695	14,469	14,229	11,720	11,586
Rank	--	--	--	--	--
Delay per Peak Auto Commuter (pers-hrs)	42	42	41	41	40
Rank	--	--	--	--	--
Travel Time Index	1.22	1.21	1.21	1.21	1.20
Rank	--	--	--	--	--
Commuter Stress Index	1.29	--	--	--	--
Rank	--	--	--	--	--
Freeway Planning Time Index (95th Pctile)	2.41	--	--	--	--
Rank	--	--	--	--	--
Congestion Cost (constant 2014 $)					
Total Cost ($ millions)	338	326	317	306	292
Rank	--	--	--	--	--
Cost per Peak Auto Commuter ($)	960	961	959	959	970
Rank	--	--	--	--	--

* Note: Cells containing "--" indicate no available data.

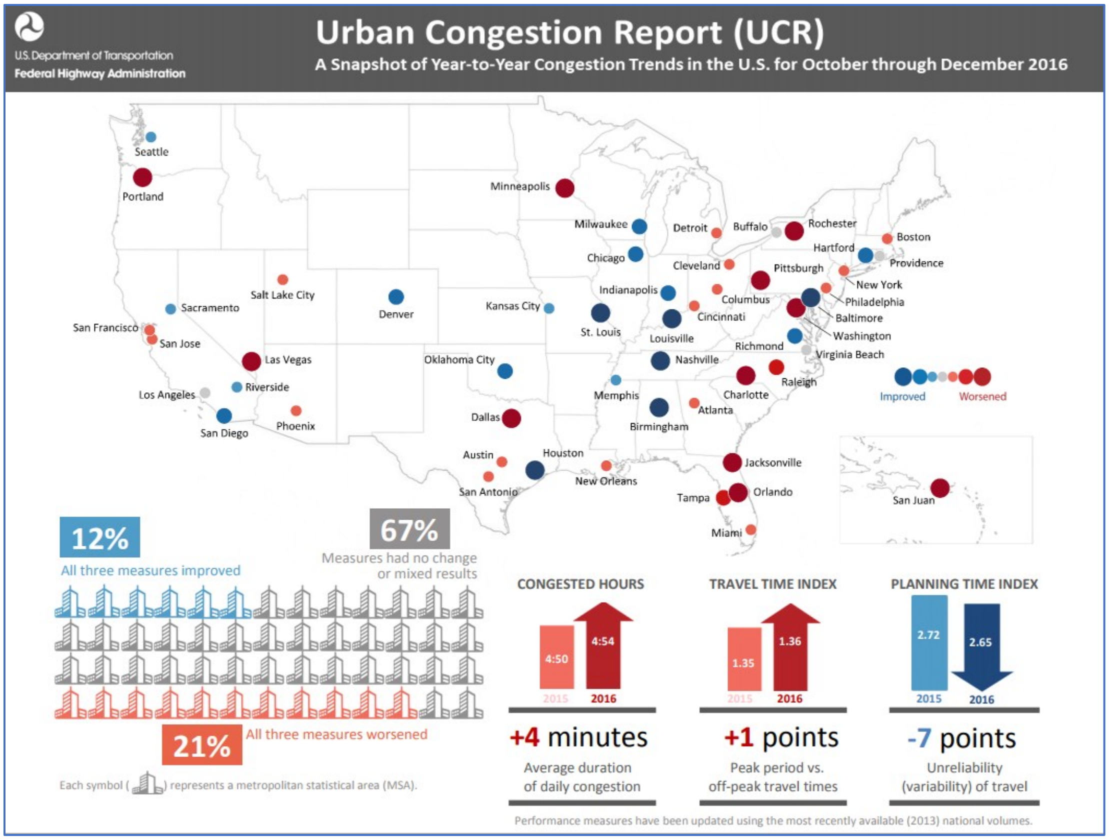
Kansas City MSA Tabular Data

The Mobility Data for Kansas City MO-KS

Inventory Measures	2014	2013	2012	2011	2010
Urban Area Information					
Population (1000s)	1,600	1,600	1,595	1,585	1,575
Rank	32	31	31	31	31
Commuters (1000s)	831	839	840	837	829
Daily Vehicle-Miles of Travel (1000s)					
Freeway	22,986	22,187	21,315	21,701	21,564
Arterial Streets	12,479	12,773	12,755	12,242	12,500
Cost Components					
Value of Time ($/hour)	17.67	17.39	17.14	16.79	16.30
Commercial Cost ($/hour)	94.04	89.60	89.56	86.81	88.12
Gasoline ($/gallon)	3.16	3.36	3.30	3.24	2.49
Diesel ($/gallon)	3.47	3.67	3.69	3.54	2.77
System Performance	**2014**	**2013**	**2012**	**2011**	**2010**
Congested Travel (% of peak VMT)	22	--	--	--	--
Congested System (% of lane-miles)	21	--	--	--	--
Congested Time (number of "Rush Hours")	2.50	--	--	--	--
Annual Excess Fuel Consumed					
Total Fuel (1000 gallons)	21,349	21,108	20,832	20,556	20,152
Rank	34	34	33	33	33
Fuel per Peak Auto Commuter (gallons)	18	18	18	18	17
Rank	62	57	55	51	58
Annual Delay					
Total Delay (1000s of person-hours)	45,570	45,055	44,466	43,878	43,015
Rank	34	33	33	34	33
Delay per Peak Auto Commuter (pers-hrs)	39	38	38	38	37
Rank	51	52	50	50	54
Travel Time Index	1.15	1.15	1.15	1.15	1.14
Rank	76	74	74	74	76
Commuter Stress Index	1.17	1.17	1.17	1.16	1.16
Rank	79	79	77	82	82
Freeway Planning Time Index (95th Pctile)	1.99	--	--	--	--
Rank	59	--	--	--	--
Congestion Cost (constant 2014 $)					
Total Cost ($ millions)	1,085	1,090	1,091	1,099	1,112
Rank	32	32	32	31	31
Cost per Peak Auto Commuter ($)	933	937	939	945	956
Rank	49	51	48	49	48

* Note: Cells containing "--" indicate no available data.

National Data (Infographic)



Appendix 3: The Challenges of Data – An Xaqt Case Study (Pothole Prediction)

Potholes are one of the most common pavement damages and often require expensive maintenance activities to repair them. Pothole formation is affected by environmental factors. Moisture can penetrate into the pavement through cracks or joints, and accumulate within or beneath the pavement structure. As freeze-thaw cycles occur, the expansion and contraction of the moisture, combined with other loads such as traffic, results in the formation of potholes[1]. Potholes lead to reduced pavement life and accelerated pavement deterioration, thus increase life-cycle costs of a pavement.

Considering contributing factors to pavement damage are all natural phenomenon, it is reasonable to apply a stochastic model that treats inputs and future states as random variables. The objective is to understand the current state of a given road segment and predict the segment's future state. A model for probability of having a pothole in the future on a segment is thus built.

The outcome variable in current state-of-the-art methods of modeling pothole formation is usually based on surface area of potholes [2–4]. All the models are based on empirical data collections dependent on particular environments, usage, and maintenance schemes. In particular, the models focused on developing countries in tropical climates. Given that the design, construction procedures, and maintenance plans vary between countries, as well as the climate conditions, none of the existing models are applicable to the routes in the US cities which accumulated pothole repair requests over time.

Data

Historical pothole reports are obtained through 311 Call Center Service Requests. Service requests for pothole repair were recorded over last 10 years. Street addresses were used for the location of pothole. Locations is mapped approximately onto the street through geocoding and calculating the shortest perpendicular distance from spatial point to street lines. A pothole is then treated as an event on a street segment occurred at the time of request repairing.

Street network is constructed based on segmented street data provided. In the network, street segments are used as edges and intersections between streets are nodes of the network. With this setting, potholes are network-constrained events, i.e. events can only occur on edges or nodes of the network. The importance to use street network is related to define spatial relationships between street segments, which is better to avoid Euclidian distance between spatial points usually used by planar spatial statistics.

Climate data Freeze-thaw cycle information is obtained through the National Centers for Environmental Information (Formerly the National Climatic Data Center, NCDC) of National Ocean and Atmospheric Administration (NOAA). Freeze-thaw cycle is defined at a daily basis, i.e. there was a freeze-thaw cycle if the minimum temperature was below 0°C and the maximum temperature was above 0°C on a day. The monthly number of cycles is used as a predictor variable. Lagged monthly number of cycles are also examined to see if they can improve model performance.

Bus routes and traffic data

Bus routes and stops data are current. There may be some changes over the study period. But we assume they are relatively stable. Traffic data on limited number of intersections was provided. Street segments connected to the intersection were identified, and assigned with the counted traffic loads based on specified compass direction of streets. We assume the average traffic loads or street were maintained stable over a 12-month period. Models on this subset will be built to examine the effect of traffics on pothole formation.

Statistical Analysis

Factors associated with pothole formation: We consider the road system as a network that consists of segments, and apply spatial network analysis methods for pothole event, which is treated as a network-constrained phenomenon [5]. Let y_i be a count value of pothole observed at segment i $(i = 1, \ldots, N)$. In this study, we consider a Poisson model for the counts. In the hierarchical framework that we consider [6], the Poisson likelihood of the observed counts is the first level of the model, which is used for modelling the within-segment variability of the event counts conditional on unknown risk parameters, i.e.

$$y_i = Poisson(\lambda_i)$$

Considering $\lambda_i = E_i \times R_i$, with R_i being the ratio between the observed event counts y_i and the expected event counts E_i for segment i. Then, we can have

$$\log \lambda_i = \log E_i + \log R_i = \log E_i + \alpha + S_i$$

That is, the ratio R_i on a logarithmic scale is split into an overall intercept a and main spatial effects S_i. The spatial dependence is represented by means of a spatial weights matrix that defines a set of spatial neighbors d_i for each unit i. A weight matrix $\boldsymbol{W} = (w_{ij})$ is then defined to measure the proximity between segments in the given network. In the simplest case, $w_{ij} = 1$ if segment i and j share a common node, and is 0 otherwise. Spatial distance-based weight matrix can be another option.

We assume E_i is associated with environmental factors, including freeze-and-thaw cycle, traffic counts, bus route, pavement condition, and seasonality, etc.

Time-to-event models will be applied to model the time from the first freeze-thaw cycle recorded in data to pothole formation. Potential contributing environmental factors to the time-to-pothole-formation will also be considered.

Prediction of pothole formation on street segment: Machine learning algorithms, including gradient boosted machine and random forest [7,8], are applied to see how good models built on the current data are in predicting pothole formation in the future. The basic idea is to obtain a predicted probability about whether there will be any pothole formed on a street segment when we have relevant data about a specific street segment. In building machine learning models, a dichotomous outcome variable is created to indicate whether there was any pothole on a segment. Predictor variables include the number of freeze-and-thaw cycle, traffic counts, bus route, and pavement condition etc. Hyperparameter tuning is based on 10-fold cross validation. Model performance is evaluated on test subset of data. The Area under Receiver Operating Characteristic (AUROC) is used as the evaluating metric of model performance. A high value of AUROC indicates a good capability of predicting the chance of pothole formation on a street segment.

Results

(1) Number of potholes over time

12666 potholes on total 366,156,006 square feet of road pavements were reported over the period of 2007 – 2015. There is no clear yearly trend on the number of pothole reports (Figure 1).

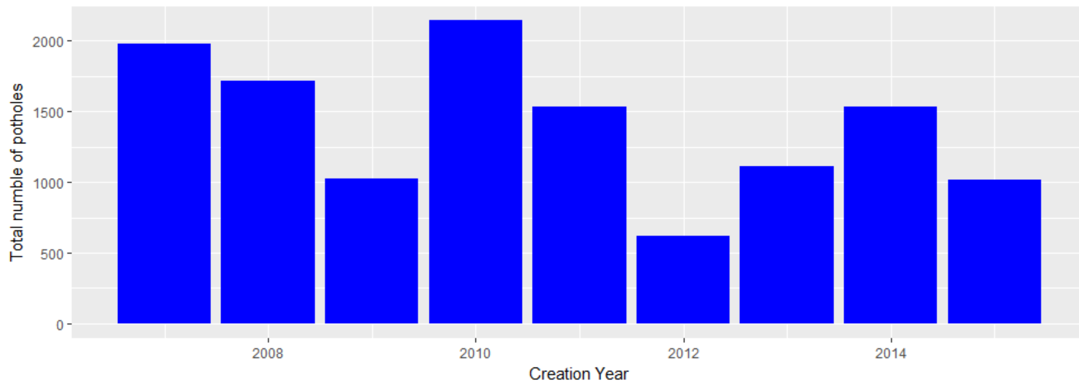


Figure 1. Fluctuation in total number of pothole reports over time.

Figure 2 shows the pattern of pothole formation over months and years. There looks a clear seasonality: pothole formations were generally peaked on February, March, and April. The peak observed in 2012 is lower than other years, which may be due to specific reason.

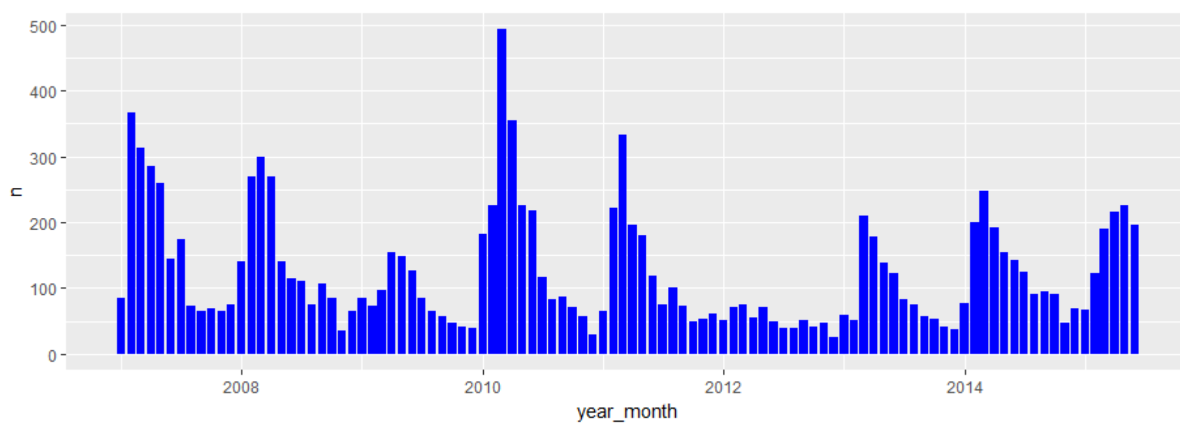


Figure 2. Number of pothole by months over year.

Relatively more potholes were reported in Jackson county over the study period when comparing with Clay and Platte county (Figure 3). However, there seems an overall decreasing trend in the rate of potholes in Jackson county, from 0.0322 per 1000 square feet in 2007 to 0.0135 per 1000 square feet in 2015.

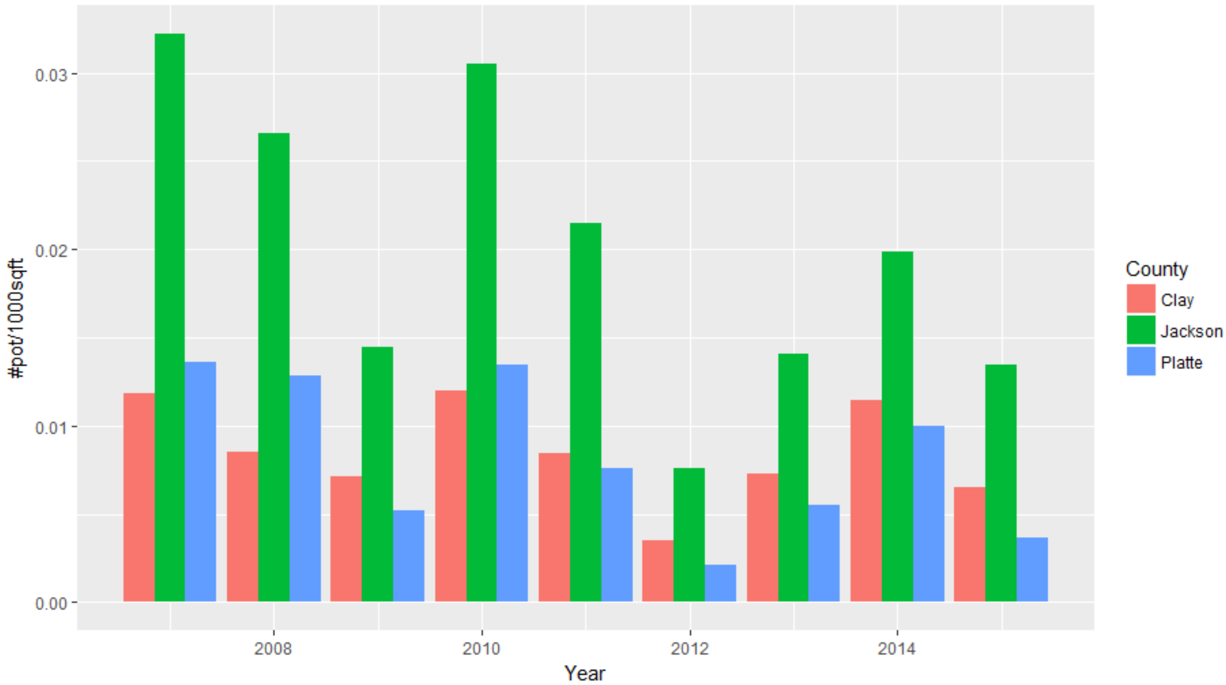


Figure 3. Number of potholes per 1000 square feet by county and year.

(2) Potholes over area

Number of potholes per 1000 square feet of pavement distributed differently over area, as Figure 2a indicates, several census tracts has found large numbers of pothole over time. By splitting the time frame into two periods, we found that less potholes were reported in recent five years (Figure 2c) when comparing with the frequencies reported during 2007-2011 (Figure 2b).

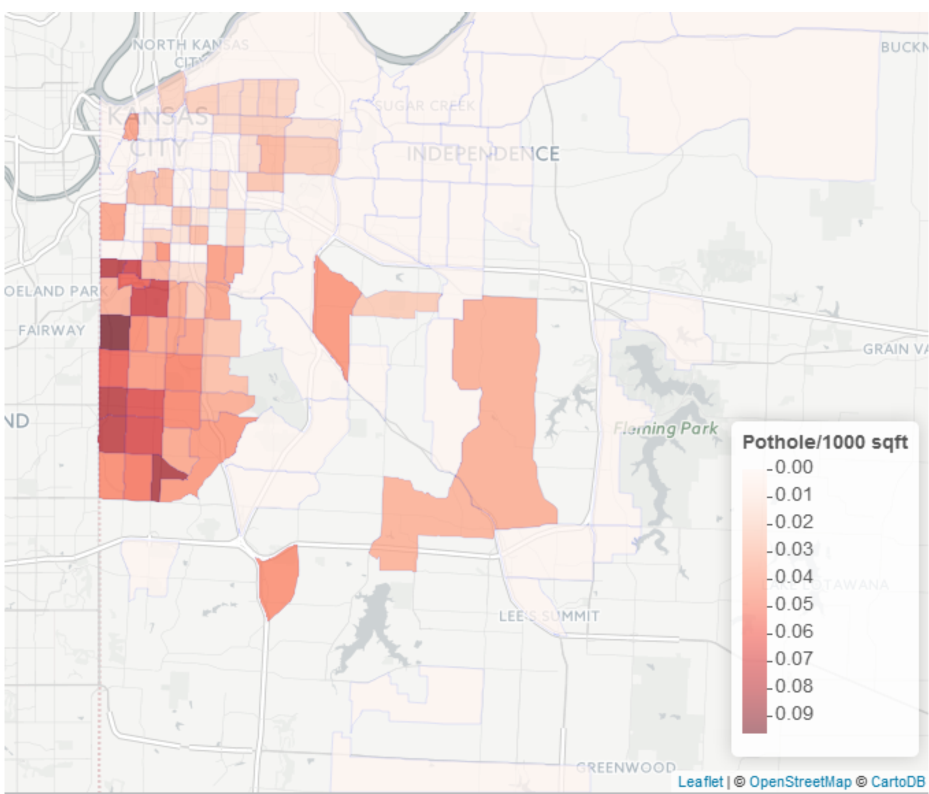


Figure 4a. Overall frequencies of pot holes on census tracts.

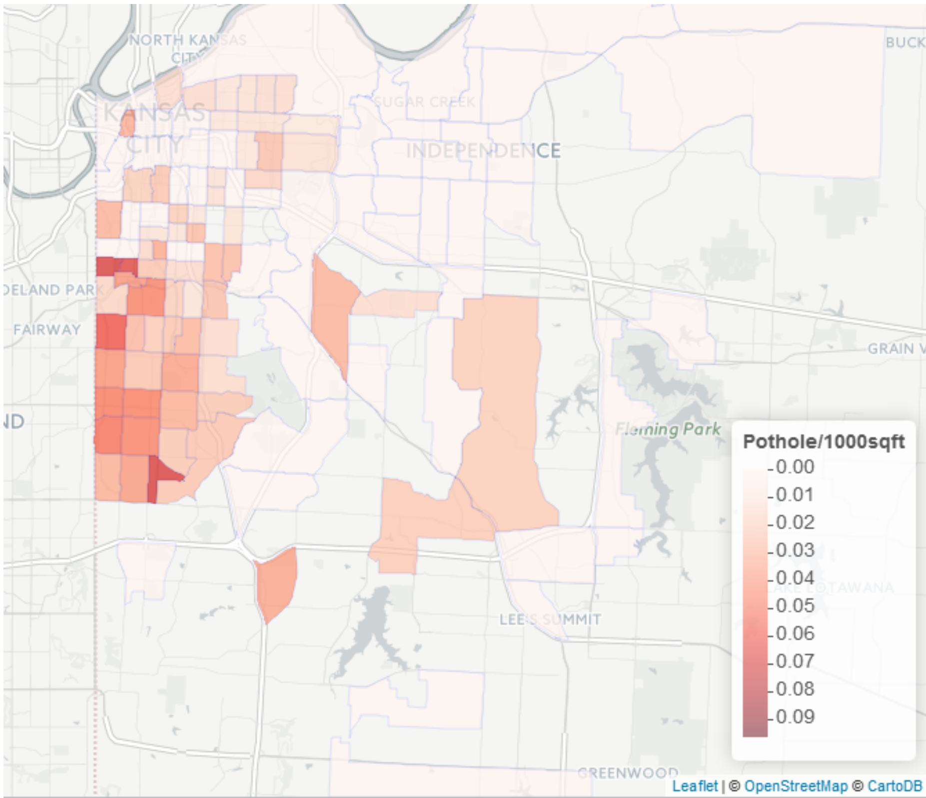


Figure 4b. Frequencies of pot holes on census tracts from 2007-2011

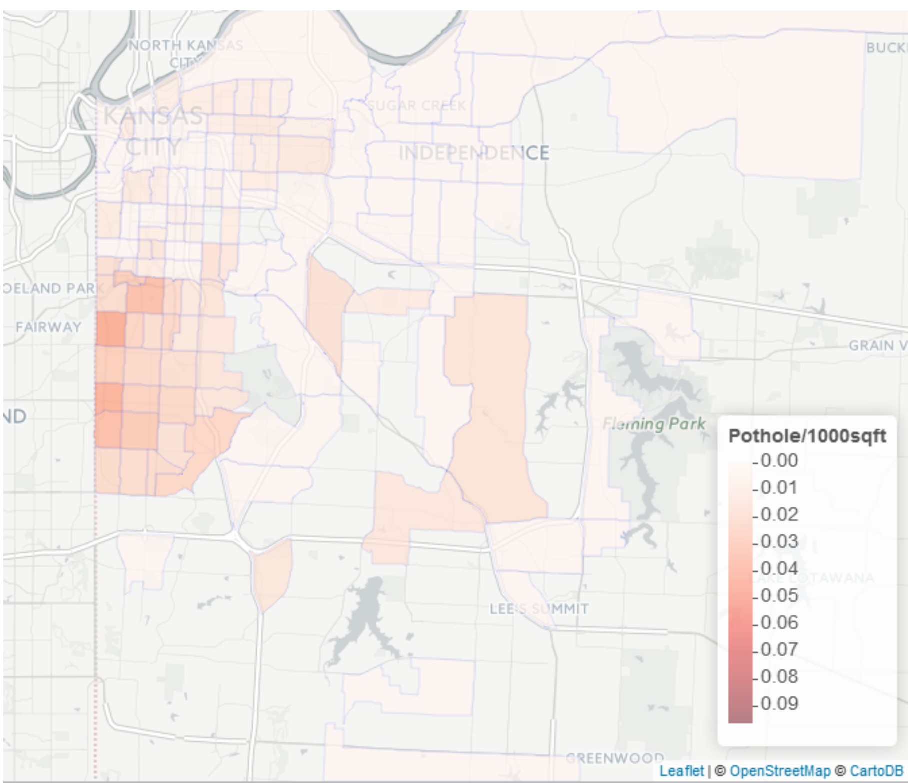


Figure 4c. Frequencies of pot holes on census tracts from 2012-2017

(3) Potholes on bus road

Assume bus routes and stops are stable over the study period, then a relatively higher rate of potholes is found on bus road than that on roads with no bus run over (Table 1). The number of potholes on bus road is 0.0444 / 1000 square feet, while it is 0.323 / 1000 square feet from non-bus road.

Table 1. Rate of potholes by bus road

Bus road	potholes	Pavement Area	Potholes/1000 sqft
No	10715	332,094,498	0.0323
Yes	1511	34,061,508	0.0444

(4) Contribution of covariates on pothole formation

Use pothole formation as the output, we examined potential contributions of available factors on pothole formation. As Table 2 indicates, OCI road condition, bus road, and number of freeze-thaw cycles are all significantly associated with pothole formation. Three lagged variables of the number of freeze-thaw cycles are also statistically significant, suggesting the delayed impact of freeze-thaw cycles.

Traffic counts were obtained on 579 intersections. Corresponding street segments are identified based on geocoded locations on records. Traffic loads were assgined on identified segments, assuming observed traffic loads were stable over 12-month period. A model is built on the subset of street segments with traffic data. Table 3 indicates that the effect of traffic loads is statistically significant while the significance of bus road and OCI conditions disappears, suggesting traffic loads may play more important role in pothole formation. One possible explanation for the insignificant effect of busline is that the number of buses was counted into traffic loads. Acknowledging the limited number of street segments in the subset, and the assumption we made about traffic loads, the model should be better if more traffic data are collected.

Table 2. Relationship between factors and pothole formation.

Effect	**Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	-4.3052	0.03578	-120.33	<.0001
OCI	-0.00446	0.000383	-11.65	<.0001
Bus road	0.1394	0.02839	4.91	<.0001
Time	0.01341	0.001030	13.01	<.0001
Time*time	-0.00021	8.989E-6	-23.43	<.0001
NFT	-0.00414	0.000380	-10.91	<.0001
NFTlag1	0.004610	0.000424	10.88	<.0001

Effect	Estimate	Standard Error	t Value	Pr > |t|
NFTlag2	0.001914	0.000404	4.74	<.0001
NFTlag3	0.007017	0.000324	21.66	<.0001

NFT: number of freeze-thaw cycle; NFTlag1: 1-month lagged NFT; NFTlag2: 2-month lagged NFT; NFTlag3: 3-month lagged NFT.

Table 3. Relationship between factors and pothole formation on the subset with traffic loads

	month	Estimate	Standard Error	t Value	Pr > |t|
Intercept		-18.0865	0.4952	-36.52	<.0001
Month	**1**	1.4074	0.4863	2.89	0.0038
	2	5.5714	0.4766	11.69	<.0001
	3	7.3424	0.4931	14.89	<.0001
	4	9.5703	0.5211	18.37	<.0001
	5	11.1508	0.5282	21.11	<.0001
	6	8.7793	0.5447	16.12	<.0001
	7	6.9908	0.5792	12.07	<.0001
	8	7.2154	0.5551	13.00	<.0001
	9	6.9782	0.5696	12.25	<.0001
	10	6.5847	0.5509	11.95	<.0001
	11	3.2933	0.5816	5.66	<.0001
Bus road		-0.08346	0.2570	-0.32	0.7454
OCI		-0.00638	0.005018	-1.27	0.2036
NFT		0.04159	0.001779	23.37	<.0001
NFTlag1		0.04041	0.001924	21.01	<.0001
NFTlag2		-0.02472	0.001410	-17.53	<.0001
NFTlag3		-0.01925	0.001501	-12.82	<.0001
Traffic Load		0.002314	0.000129	17.89	<.0001

NFT: number of freeze-thaw cycle; NFTlag1: 1-month lagged NFT; NFTlag2: 2-month lagged NFT; NFTlag3: 3-month lagged NFT.

(5) Machine learning algorithms for predicting pothole formation

Gradient boosted machine (GBM) and random forest algorithm are tested to see how accuracy of models to predict pothole formation. The two algorithms handle well for potential non-linear relationship between outcome variables and predictors. By grid search method with 10-fold cross validation, hyperparameters of each model are specified. The selected set of hyperparameters for GBM includes 12 for the interaction depth, 1500 for the number of trees, 0.01 as the shrinkage, and 14 for the minimum number of observation in node. For the random forest algorithm, the number of predictors sampled for splitting at each node is set to be 2 (Figure 5), and 500 is used as the number of trees.

Table 4 lists the performances of the two algorithms for predicting pothole formation. By AUC, GBM gives 0.735(95% confidence limit: 0.727 - 0.743), performing better than random forest.

Appendix 4: GCTC Supercluster Workshop – The Raw Data

The following pages are a transcription from the handwritten notes. It should be noted that many of the pages were hard to read due to penmanship and a certain degree of interpretation was used to compile into any type of meaningful format. The transcription also reflects typographical errors, grammatical errors and is incomplete in parts to try and accurately reflect the raw data.

TABLE 1 SESSION 1: City [???] Spain, Cal State, Amazon Web, Sinius computer solutions

Smart City projects in Asia and all over Europe
Problems: crimes - Real time data sharing, breaking down silos, political issues
??? : 1. keeping sensitive data safe
2. ROI
3. what are our comparative values?
4. How prepared are we for the future?

SESSION 2: ???

Daniel: Crime is not part of smart city mentality. Not part of daily mentality / psyche. If go to Spain / Europe, may need new word to include / address crime.
Measuring: ROI? Comparative values, _____ movement corrective data is needed down ____ chain

SESSION 3: ??

Needs to apprend & _____ data homeless issue ____ . PII vs aggregate data danger of profiling red lining ___? cloud security more secure than ____

Session 4: City of Blue Springs, Dr. Rhee, Psicurity, citibrain, LK Communications

Trade off to developer for additional R.O.W. for the future internet needs. landscaping revolution. TIF or often similar financing tools, set backs? Connectivity Internet & physical on forefront, aggressive toward public / private cooperation. Snap shot of demographics and other usable information on city website. Helps people and business see what's available. Public works and community development work closely with third party utility providers and developers to address current needs and brainstorm future needs and desires. acknowledge private side needs and incentive to come and city wants them to, look for win win opportunities.
Hurdles with collecting, saving and sharing data: need state and federal guidance and participation (i.e. HIPA and private data.)
City concerns with internal network risks, need for secure systems conflicts with open sharing and access. Currently technology direction has been securing network and infrastructure that exists. Future planning for IT is free wifi and downtown and other public places. What for staff is more IT personnel to help departments link information in a way that it helps planning and efficiency.
Conversation veered off into cyber security in regards to infrastructure and city maintained data. Looking to state and feds for funding, but very limited. City funding this is putting off other needed improvements and repairs to protect systems and information in place. these cyber security threats and other infrastructure security concerns are coming to the fore front with cyber being the hardest to prepare for.

TABLE 2 - SESSION 1: US Ignite, Fiware, city of Bellvue, City of Nashville (vanderbilt), CA Technologies, Ubiquia, CISCO
Bellvue:
1. Traffic issue because of growth
2. affordable housing
3. increase water quality
4. need to move forward in data use
5. so much real time data to store with new water sensors

SESSION 2: City of Bellvue, City of Lincoln, City of Nashville, CA Tech, KC Digital Drive

1. How to operationalize your data?
CA Tech: live API creator
BELLVUE: getting inventory and understanding the "flow of data," can also take safety complaints from NextDoor (which is a 3rd party app they use) and deploy more officers in neighborhoods where crime is increased)
LINCOLN: getting geographic and census data to find out how close the residents are to the city.
2. How can we maximize data, get in one place, useful in one place?
VERIZON: pick an open source platform so all developers can resolve issues
UMKC: some cities want to rely on a few industries, but the data should be open source instead
BELLVUE: we use socrata
VERIZON: data sovereignty is a BIG DEAL in places outside U.S.
Bellvue: Can't have open source traffic programs, but we should have that for data
VERIZON: we should automate the data use so that quick actions can be done w/o human contact (traffic lights responding in a hurricane)
Bellvue: we're not there yet
3. Defining a business model?
NASHVILLE AND LINCOLN: need to search for ROI in their research as well as universities (why would a city want this info, how can they apply it?)
CA TECH: provide the data so it can be monetized.
BRANSON: sell tourism data
NEBRASKA: better walkability in neighborhoods (the topic of research) means higher real estate prices, also if people are walking more, they are more healthy.

SESSION 3: CISCO, CA tech, city of Lincoln, city of nashville, city of kansas city, NIST, SIG Spain, KC Digital

LINCOLN: collecting abnormality of walking patterns. How do we measure? abnormal walking pattern, different gait, i.e. pothole in the area, changes strige. How will the city use it? real time, index to measure street condition. Perhaps it won't be useful?
KC: 1. have goal 2. outcome indicators for goal. 3. what influences those things. e.g. quality of life -> city services -> satisfaction with quality of communication from the city. How do you measure communication?
CISCO: sit down with city and stakeholders, aly out success map. "journey map." Success = happy city. For some cities, succcess is immediate satisfaction for EMPLOYEES, efficiency. KPI: external = happiness; internal: efficiency, satirsfaction
KC biggest gains have been in engagement, transparency. KPI may not be MONEY or EFFICIENCY

Impact or unintended consequences: identify them in every department that is not yours, how changing a street light to automated might affect departments other than traffic department. Engage the employees and ask them how those decisions would affect them.

SESSION 4 : MISSING

TABLE 3: SESSION 1 Missing

SESSION 2: [herb notes?]

PUBLIC HEALTH: tax info of homes, who owns it, qualify for [something] income, proof of operating in home. FEDERAL GRANT: top down and bottom up ___ info American vs. selection [???] Hidden cost of transformation ___ efficiency reduction [?]

SESSION 3:
MISSING

SESSION 4: MISSING

TABLE 4 SESSION 1: MISSING

SESSION 2: MISSING

SESSION 3: Unite PRivate Networks, Cty of Akron Ohio, Alabama Utility, Cisco

NEEDS: better IT personnel to work with desk ideas to collect and interpret data. Water & sewer treatment not the issue: collection and distribution system maintenance is. Implement technology sensors to monitor flow to help identify leaks and more important areas to repair / replace. Install extras (fiber, often utilities, etc.) while replacing sewer and water mains. Better plan with EPA, more solutions, help less litigation and expenses that come with it. Implement more technology (wifi etc.) to keep population in the city and grow. Implement plans for [??] and connectivity.
NEEDS: better communicatoin and reporting between public utility and service departments. IT is huge, need shared date from 311 calls and other collection sources, IT setup and tracking method and set goals to address / improve. Track efficiency of departments, share across departments if need, contract with other sourced to prevent idle staff/ costs. Identify and tackle large waste ____ done quicker. Technology key in finding leaks, [detonated?] lines, pipes, etc. then proper cataloguing through software to help implement plan to address.

SESSION 4:

MISSING

TABLE 5 MISSING
TABLE 6 MISSING

TABLE 7 SESSION 1 (Sprint, Branson, Nokia, Sweden, AWS, Velocity, Ubicquia, Kansas City)

1. Parking

2. Congestion
3. crime -> surveillance = right to privacy
4. citizen services
5. energy
6. communication with older generations

SESSION 2 MISSING

SESSION 3 KCMO, Branson, Sweden, Cisco, Sensity, Nokia, AWS

BRANSON: Community survey (every other year, does not include visitors,) External entity surveys for visitors, a traffic sync [?] that would improve traffic congestion (so that's measurable,) Mental health patients sent to branson facilitate / fufill program
KC: rolling 5 year plan, annual update, objective -> goals -> plan -> budget . Importance to citizen / performance against KPI = weighted score.

SESSION 4 MISSING

TABLE 8 SESSION 1 MISSING

SESSION 2 : Sprint, MEC, UPN Fiber, NSF, U. of Omaha, KCMO, Fiware

1. Doesn't need to be private - public. Can be multiple public. Create open source platform that you can gather multiple stakeholders around. 2. NSF is launching a similar program w an industry cornsortium that brought in $50 m in kind donations
3. Govt Model: goals can provide access to conduits for free for companies to access (permits waived?)
4. In KCMO, Sprint build wifi network, city provides fiber access and free rent / utilities. Also sprint has the ability to add cellular to poles, no profit for sprint but it has lowered costs. probides better experience for sprint customers. Provides overflow capacity for major events
return for city: providing a spine for business to utilize for growth
ROI for cities: improved efficiency / effectiveness in cities

SESSION 3 : MISSING

SESSION 4 : MISSING

TABLE 9 SESSION 1 Akron Ohio, Gartner, Ubiquia, Sprint, Mindtack, Kansas City

AKRON:
- cool but not smart
- EDC investments but not in tech
- Lack of experience and openness in tech
- Lack of funds
- Water quality
- What do taxpayers want? What do city employees need?
  - What accomplishes both?
- Leveraging funding that we do have
- Need to understand the path forward

PRIORITIES:
Transparency of systems and data

Sewer and water (issue with EPA mandate)
- Combined overflow
- Rerouting runoff
- Sewer rates 3 x peers

How do we stop brain drain?
- Use data to improve retention
- How do we help local tech get noticed and find talent
- Readt to do a study on roadmapping

How do we leverage local educational resources?
Improving 311 (providing data) no current platform

Not enough focus on innovatoin in the "how to pay for it" city thinking.
Competing with legacy assets is an issue.
(ATT blocked a fiber install in AKRON)

1. Think of light poles at right of way
   a. Monetize the city assets by selling rights
   b. How long is appropriate for leasing rights? E.g. "top of pole" leased for 99 years
2. ESCOs

Biggest opportunity is in business model innovation

Boundary and jurisdictional issues
- How do we ensure communicatoin over the walls (or tear them down entirely)

Similar problems may require different solutions in different places
How do we identify and leverage windows of opporunity
How do we scale development to include the whole city, not just small specific regions

SESSION 2: Akron, Gartner, Mind Teck, Sprint, Think Big

1. What are the issues?
- rain water management
- tap water quality.

Solution: City water manager has requested an app.
we need MORE water data, citizen sourced, sewer installed sensors.
Problem in this context is a lack of data rather than analytics.

Improve means of ingesting information
- improving efficiency of flow of info as it comes from citizens.
- Water department itself actually has three silos that often are not aligned
- Take county real estate data and tie it to water department data.
- Smart meters to prevent Water Fraud
- Water quality = big issue because of aged infrastructure - need mechanism to citizen source water quality issues.
- "Water alerts" for abnormal usage rates. We don't want to be flint, michigan.

- Feed the dta into our school systems in order to leverage their intellectual capital to develop localized solutions. Need to centralize GIS so we can facilitate layering of data from all other silos.

Find mission critical sensor locations so we can minimize hardware / install costs
Map crime to code violation to 311.

Using data to increase population (like placement rates after college) -> is university data openly available?
Communicating resources available effectively to citizens.

SESSION 3 : Akron OH, St. Louis, Think Big, Nokia, Sirius, UNL, KC Chamber

the data is everywhere
- but only where it is

on disparate platforms
- one literally still on lotus.

St. Louis has a non-profit that acts as collector and ______ of smart city data
- creating a central data exchange that lives outside the government.
- Switch sit for local service providers. seating cities and entrepreneurs at the same table.
- Need to ensure data collected helps as many people as possible.

Build bridges between cities and counties to maximize ROI for citizens. Must ensure that any centralized or open data sets protect our citizens.

Do we continue down microsoft / oracle paths or go all open source: co development but also hackable.
Physically, where does the data live?
- one stop shop app for citizens to interact with government

SESSION 4: Think Big, KC Chamber, Here, Amazon Web services

- Leverage local knowledge and creative talents by engaging academic institutions (interns not converting.) Cross departmental consulting services e.x. If department paid by water department for services (that income invested in better IT assets)
- Leveraging large IT companies, Filtering all infrastructure projects through a central "smart city" lens to ensure opportunities are not missed.
- Engage local "chambers" to support.
- Publish city goals and problems and challenge citizens to participate in their own rescue.
- Look at Marriott as an example (look at commercialization and spin out of as many pieces as possible.
- Adopt as a service model, outsourcing only optimizing for cost efficiency, private companies are setting citizens expectations for service delivery and have generally developed a profitable model.
- ESCO modeling (financial benefit of cost of sewing exchanged for new / improved systems / services.

Start with a solid foundational architecture (avoid opportunities and ultimately disparate solutions)
focus on building ecosystem, not a platform

TABLE 10 - SESSION 1: XAQT; UMKC; Branson, MO.; KC International Airport; Edison Awards; Vanderbilt

BRANSON: 1. anticipate needs of tourists 2. residents have to pay for this construction 3. what ROI area cities seeing for their smart city investment? What data and measure ments should be built into [?] from the beginning to calculate ROI? How best to communicate with community?
KCI AIRPORT: 1. learn a person's background when they fly (how often they fly, what time of day) 2. Communicated value of airport to community 3. KCI Municipal airport can't get the funds, International is fine.
City - education - industry, all must communicate.
Phyiscal infrastructure: need to anticipate shelf life: what upcoming innovations will make the current innovation obsolete?
cyber security: safety vs. privacy

SESSION 2 UMKC, KCI Airport, United Private (?), Edison Awards

KANSAS CITY
1. how do we pick data to support our needs?
2. IDEA: make one wing of old airport into pet adoption, pet rescue to get public buy in from citizens resisting airport plan. (???)
2. Smart tech at airports include sensors in ceiling and at the ticket counter
3. trace iphone from time person disembarks: how long they stay in town, which hotels they go to, tell mayor that we need more theaters / restaurants in ___ areas
4. sensors in bus stations to see # of people and average wait times
5. Light rail from KCI to KC?
SOLUTION: measure time it takes to arrive to board their plane...
BRANSON: TRAFFIC: traffic data [I guess they need it...?] accident / traffic deaths, flight data from airport vehicle emission reduction
competitors would like Branson's data
Monorails for branson?
ITALY: creates a data platform for his city, there is lots of data that is useful that no one really knew about.

SESSION 3 KCMO, Edison, ___, _____
Illelligle
SESSION 4 ___, _____ ???
Illelligble

TABLE 12 - SESSION 1: ???

Kansas City:
1. Unknown true coverage area for Google Fiber in KC
2.ensure all residents understand smart city initiative and discover their needs
3. define digital divide

4. access to education

SESSION 2: ??

Data sets for defining the digital divide.
1. What data is accessible today? Broadband via FCC because it tracks connectivity, so you can track it by household income (?)
2. need data accessible from healthcare / utility / transportation? U.S. Census data, open data catalogue, cities sharing data.
Health Department: HIPPA compliance, security breaches, educations: missed days / sick days correlate with visits to the health clinic?

SESSION 3 ??

City has monthy / weekly scorecard with overview of identified KPI's to show leading/ logging indicators. Keep it automated to reduce human error (i.e. waiting to report unfavorable data until it seems favorable) have mayor get a scorecard every morning with his / her identified KPI's. Track inventory and assets. All data points collected accross the city housed in a single data catalogue with internal city accesss and a mitigated public access.
Garbage collection KPI's: response time, illegal dumping down, streamlined garbage colelction, asset tracking/ life cycle replacement (eqt. replaced how often?) code violations
Health Department: HIPA compliance: security data breaches
PUBLIC HEALTH: childhood education levels, CDC data, health clinic visits, environmental impacts (smog / air quality / water quality) city cleanliness (trash pickup / street sweeper / recycling)

SESSION 4: missing

UNEXPLAINED PAGES:

TABLE 11 SESSION 3 : KPIS: ????
Different categories of KPI's to consider: demand, output, outcome, efficiency.
South beach [?]
- Enterprise, HR data, 311, data, finance
- Services: specific to departments

Budget variances
Hr absenteeism
311 cost percall

Need more real time assessment of conditions in neighborhoods, streets

What are correlates between KPI's
Data ___ be in context
How do you communicate data in the right way?
How do you know a smart city is successful?
Can we connect with k -12 on open date

# of wifi connections for tourism
- Defining smart for regular residents
- Why we did it
- Why it's useful

Local marketing!
- Different message for different demographics

???SESSION ???TABLE: mayor of branson, comm mgr Jennifer Langford, Steve Morgan @ Unite PVT Network, KC Tech and Sustainability

Cost savings $60/K / month + reduce cost of firewalls and then security software and solutions
MORENET - OTC
Charge a premium to utilities woh don't opt in now to under____ utilities with us - they will have to pay a premium any time they need to get in to work on their utilities
Lighting controls for energy management
Data collection via video surveillance solutions that monitor traffic for incident assessment and communication for proper resource response. Also, to create traffic flow solutions over IoT signal change options based on use periods. And customed profiles to help better identify our real demographics and their needs, preferences and perceptions

Appendix 5: Interpretations of GCTC Supercluster Workshop Synthesized Raw Data

The feedback from the GCTC workshop was insightful and yielded some great conversations that resulted in new questions to be answered – but was also somewhat inconclusive in the raw form. The following is an extract of recurring words that indicate themes for further analysis and discussion in this white paper.

Below is an analysis of the 1, 2 and 3 word combinations that appeared most frequently in the handwritten narratives across all sessions:

Top 20 Most Repeated 1 Word		Top 20 Most Repeated 2 Words		Top 20 Most Repeated 3 Words	
1. data	**59 *(2%)***	1. do we	9 *(0.3%)*	1. how do we	6 *(0.2%)*
2. city	47 *(1.6%)*	2. how do	9 *(0.3%)*	2. city of nashville	3 *(0.1%)*
3. session	37 *(1.3%)*	3. city of	9 *(0.3%)*	3. how do you	3 *(0.1%)*
4. how	22 *(0.8%)*	4. need to	8 *(0.3%)*	4. session 4: missing	3 *(0.1%)*
5. need	19 *(0.7%)*	5. [ ]	7 *(0.2%)*	5. session 3 :	3 *(0.1%)*
6. water	**18 *(0.6%)***	6. missing session	7 *(0.2%)*	6. session 4 :	2 *(0.1%)*
7. missing	15 *(0.5%)*	7. missing table	7 *(0.2%)*	7. city of bellvue	2 *(0.1%)*
8. table	13 *(0.4%)*	8. smart city	7 *(0.2%)*	8. of bellvue city	2 *(0.1%)*
9. smart	11 *(0.4%)*	9. session 3	6 *(0.2%)*	9. bellvue city of	2 *(0.1%)*
10. efficiency	**10 *(0.3%)***	**10. water quality**	**6 *(0.2%)***	**10. have to pay**	**2 *(0.1%)***
11. traffic	**10 *(0.3%)***	11. the city	6 *(0.2%)*	11. issue because of	2 *(0.1%)*
12. public	10 *(0.3%)*	**12. data to**	**5 *(0.2%)***	12. city of lincoln	2 *(0.1%)*
13. open	**9 *(0.3%)***	**13. the data**	**5 *(0.2%)***	13. of lincoln city	2 *(0.1%)*
14. time	**9 *(0.3%)***	14. session 4:	5 *(0.2%)*	14. lincoln city of	2 *(0.1%)*
15. needs	9 *(0.3%)*	15. session 1:	5 *(0.2%)*	**15. in one place**	**2 *(0.1%)***
16. quality	**9 *(0.3%)***	16. session 2:	5 *(0.2%)*	**16. open source platform**	2 *(0.1%)*
17. kc	8 *(0.3%)*	17. session 3:	4 *(0.1%)*	17. for the future	2 *(0.1%)*
18. sprint	8 *(0.3%)*	18. kansas city	4 *(0.1%)*	18. not part of	2 *(0.1%)*
19. solutions	8 *(0.3%)*	19. to help	4 *(0.1%)*	**19. real time data**	**2 *(0.1%)***
20. citizens	**8 *(0.3%)***	**20. of data**	**4 *(0.1%)***	20. 4 : missing	2 *(0.1%)*
Word Analysis from Session Notes (Raw Data)					

Top 100 Most Repeated Words (Raw)	#1-50
1. data	59 *(2%)*
2. city	47 *(1.6%)*
3. session	37 *(1.3%)*
4. how	22 *(0.8%)*
5. need	19 *(0.7%)*
6. water	18 *(0.6%)*
7. missing	15 *(0.5%)*
8. table	13 *(0.4%)*
9. smart	11 *(0.4%)*
10. efficiency	10 *(0.3%)*
11. traffic	10 *(0.3%)*
12. public	10 *(0.3%)*
13. open	9 *(0.3%)*
14. time	9 *(0.3%)*
15. needs	9 *(0.3%)*
16. quality	9 *(0.3%)*
17. kc	8 *(0.3%)*
18. sprint	8 *(0.3%)*
19. solutions	8 *(0.3%)*
20. citizens	8 *(0.3%)*
21. roi	7 *(0.2%)*
22. better	7 *(0.2%)*
23. security	7 *(0.2%)*
24. private	7 *(0.2%)*
25. airport	7 *(0.2%)*
26. ___	7 *(0.2%)*
27. tech	7 *(0.2%)*
28. down	7 *(0.2%)*
29. real	7 *(0.2%)*
30. cities	7 *(0.2%)*
31. >	7 *(0.2%)*
32. local	6 *(0.2%)*
33. get	6 *(0.2%)*
34. branson	6 *(0.2%)*
35. access	6 *(0.2%)*
36. cost	6 *(0.2%)*
37. department	6 *(0.2%)*
38. 2:	6 *(0.2%)*
39. services	6 *(0.2%)*
40. help	6 *(0.2%)*
41. different	6 *(0.2%)*
42. departments	6 *(0.2%)*
43. fiber	5 *(0.2%)*
44. 3:	5 *(0.2%)*
45. bellvue:	5 *(0.2%)*
46. issue	5 *(0.2%)*
47. 311	5 *(0.2%)*
48. issues	5 *(0.2%)*
49. sensors	5 *(0.2%)*
50. kansas	5 *(0.2%)*

Top 100 Most Repeated Words (Raw)	#51-100
51. sewer	5 *(0.2%)*
52. systems	5 *(0.2%)*
53. akron	5 *(0.2%)*
54. 1:	5 *(0.2%)*
55. infrastructure	5 *(0.2%)*
56. identify	5 *(0.2%)*
57. crime	5 *(0.2%)*
58. source	5 *(0.2%)*
59. platform	5 *(0.2%)*
60. ensure	5 *(0.2%)*
61. big	5 *(0.2%)*
62. plan	5 *(0.2%)*
63. 4:	5 *(0.2%)*
64. health	5 *(0.2%)*
65. utilities	5 *(0.2%)*
66. measure	5 *(0.2%)*
67. ca	5 *(0.2%)*
68. goals	4 *(0.1%)*
69. leverage	4 *(0.1%)*
70. service	4 *(0.1%)*
71. network	4 *(0.1%)*
72. include	4 *(0.1%)*
73. kci	4 *(0.1%)*
74. technology	4 *(0.1%)*
75. digital	4 *(0.1%)*
76. flow	4 *(0.1%)*
77. information	4 *(0.1%)*
78. sharing	4 *(0.1%)*
79. address	4 *(0.1%)*
80. people	4 *(0.1%)*
81. business	4 *(0.1%)*
82. wifi	4 *(0.1%)*
83. kcmo	4 *(0.1%)*
84. community	4 *(0.1%)*
85. future	4 *(0.1%)*
86. residents	4 *(0.1%)*
87. ____	4 *(0.1%)*
88. citizen	4 *(0.1%)*
89. useful	4 *(0.1%)*
90. communication	4 *(0.1%)*
91. cyber	4 *(0.1%)*
92. think	4 *(0.1%)*
93. want	4 *(0.1%)*
94. should	4 *(0.1%)*
95. implement	4 *(0.1%)*
96. nashville	4 *(0.1%)*
97. utility	4 *(0.1%)*
98. _____	4 *(0.1%)*
99. model	4 *(0.1%)*
100. cisco	4 *(0.1%)*

Extract of Top 100 Most Repeated Words (Filtered)		People	Process	City	IoT / Tech
1. data	59 *(2%)*				
2. city	47 *(1.6%)*				
3. session	37 *(1.3%)*				
4. how	22 *(0.8%)*				
5. need	19 *(0.7%)*				
6. water	18 *(0.6%)*				
7. missing	15 *(0.5%)*				
8. table	13 *(0.4%)*				
9. smart	11 *(0.4%)*				
10. efficiency	10 *(0.3%)*				
11. traffic	10 *(0.3%)*				
12. public	10 *(0.3%)*				
13. open	9 *(0.3%)*				
14. time	9 *(0.3%)*				
15. needs	9 *(0.3%)*				
16. quality	9 *(0.3%)*				
17. kc	8 *(0.3%)*				
18. sprint	8 *(0.3%)*				
19. solutions	8 *(0.3%)*				
20. citizens	8 *(0.3%)*				
21. roi	7 *(0.2%)*				
22. better	7 *(0.2%)*				
23. security	7 *(0.2%)*				
24. private	7 *(0.2%)*				
25. airport	7 *(0.2%)*				
26. ___	7 *(0.2%)*				
27. tech	7 *(0.2%)*				
28. down	7 *(0.2%)*				
29. real	7 *(0.2%)*				
30. cities	7 *(0.2%)*				
31. >	7 *(0.2%)*				
32. local	6 *(0.2%)*				
33. get	6 *(0.2%)*				
34. branson	6 *(0.2%)*				
35. access	6 *(0.2%)*				
36. cost	6 *(0.2%)*				
37. department	6 *(0.2%)*				
38. 2:	6 *(0.2%)*				
39. services	6 *(0.2%)*				
40. help	6 *(0.2%)*				
41. different	6 *(0.2%)*				
42. departments	6 *(0.2%)*				
43. fiber	5 *(0.2%)*				
44. 3:	5 *(0.2%)*				
45. bellvue:	5 *(0.2%)*				
46. issue	5 *(0.2%)*				
47. 311	5 *(0.2%)*				
48. issues	5 *(0.2%)*				
49. sensors	5 *(0.2%)*				
50. kansas	5 *(0.2%)*				

Extract of Top 100 Most Repeated Words (Filtered)		People	Process	City	IoT / Tech
51. sewer	5 *(0.2%)*				
52. systems	5 *(0.2%)*				
53. akron	5 *(0.2%)*				
54. 1:	5 *(0.2%)*				
55. infrastructure	5 *(0.2%)*				
56. identify	5 *(0.2%)*				
57. crime	5 *(0.2%)*				
58. source	5 *(0.2%)*				
59. platform	5 *(0.2%)*				
60. ensure	5 *(0.2%)*				
61. big	5 *(0.2%)*				
62. plan	5 *(0.2%)*				
63. 4:	5 *(0.2%)*				
64. health	5 *(0.2%)*				
65. utilities	5 *(0.2%)*				
66. measure	5 *(0.2%)*				
67. ca	5 *(0.2%)*				
68. goals	4 *(0.1%)*				
69. leverage	4 *(0.1%)*				
70. service	4 *(0.1%)*				
71. network	4 *(0.1%)*				
72. include	4 *(0.1%)*				
73. kci	4 *(0.1%)*				
74. technology	4 *(0.1%)*				
75. digital	4 *(0.1%)*				
76. flow	4 *(0.1%)*				
77. information	4 *(0.1%)*				
78. sharing	4 *(0.1%)*				
79. address	4 *(0.1%)*				
80. people	4 *(0.1%)*				
81. business	4 *(0.1%)*				
82. wifi	4 *(0.1%)*				
83. kcmo	4 *(0.1%)*				
84. community	4 *(0.1%)*				
85. future	4 *(0.1%)*				
86. residents	4 *(0.1%)*				
87. ____	4 *(0.1%)*				
88. citizen	4 *(0.1%)*				
89. useful	4 *(0.1%)*				
90. communication	4 *(0.1%)*				
91. cyber	4 *(0.1%)*				
92. think	4 *(0.1%)*				
93. want	4 *(0.1%)*				
94. should	4 *(0.1%)*				
95. implement	4 *(0.1%)*				
96. nashville	4 *(0.1%)*				
97. utility	4 *(0.1%)*				
98. _____	4 *(0.1%)*				
99. model	4 *(0.1%)*				
100. cisco	4 *(0.1%)*				
Legend	Primary				
	Supporting				

Appendix 5: Participants

First Name	Last Name	Organization
Ian	Aaron	Ubicquia
Changbum	Ahn	University of Nebraska
Neil	Anderson	City of Wilminton, NC
Geoff	Arnold	Verizon
Aaron	Attebery	Black & Veatch
Jonathan	Bahmani	UPN Fiber
Kalena	Beckley	Gartner
Terry	Bellinger	UPN Fiber
Kate	Bender	City of KCMO - SME
Bob	Bennett	City of KCMO - SME
Karen	Best	Mayor, City of Branson, MO
Rahul	Bhardwaj	Georgetown
Oscar	Bode	Smart City Capital
William	Branham	21st Century Telecom
Kate	Brazier	
Kevin	Brooks	Amazon Web Services
Evrim	Bunn	Department of Homeland Security
Rebecca	Chisolm	Cisco Systems
Baek-Young	Choi	UMKC
H. Michael	Chung	Cal State Long Beach
Diogo	Correia	Ubiwhere (Portugal)
Chris	Crosby	Xaqt
Dennis	Crow	USDA
Andrea	Cruciani	TeamDev (Italy)
Patty	Daley	City of Akron, OH
Dominique	Davison	Plan It Impact
Aaron	Deacon	KC Digital Drive
Michael	Demers	Missouri Department of Transportation
Justin	Dickstein	Black & Veatch
Rebecca	Dove	Pennez
Abhishek	Dubey	City of Nashville, TN
Hannah	Emerson	City of KCMO - CIO Office
David	Evans	City of KCMO - SME
Ella	Fejer	British Consulate
Jamie	Felton	Sirius Computer Solutions
Brandon	Freeman	Leidos
Anne	Froble	Cisco Systems
Narbeli	Galindo	City of KCMO - SME
Ariel	Galinsky	Capester

First Name	Last Name	Organization
Santiago	Garces	City of South Bend, IN
Kate	Garman	City of KCMO - SME
Tim	Gates	
Wes	Geisenberger	Oracle
Olaf-Gerd	Gemein	Smart City Lab
Kelly	Gilbert	KC Metro
Jose	Gonzalez	FIWARE
Richard	Greene	City of Birmingham, AL
Kovar	Gregory	CA Technologies
Katherine	Hambrick	KC Digital Drive
Lee	Hinkle	City of KCMO - SME
Douglas	Hohulin	Nokia
Dan	Horrigan	City of Akron, OH
David	Jacobus	City of KCMO - SME
Randy	Johnson	Missouri Department of Transportation
Hunter	Johnston	Think Big Partners
Naser	Jouhari	City of KCMO - SME
Majid	Khan	Verizon
Hyunsoo	Kim	University of Nebraska
Marybeth	Kochis	Xaqt
Jennifer	Langford	City of Branson, MO
Dennis	Leonard	City of Birmingham, AL
Alberto	Leon-Garcia	City of Toronto
Howard	Lock	Amazon Web Services
Maria	Lonnberg	Embassy of Sweden, Office of Science and Innovation
Mike	Mainthow	City Post
Mindy	Manes	Edison Awards
Kevin	Masingale	CA Technologies
Nick	Maynard	USG/NSF Team
Dave	McKinney	Sprint
Petros	Mekonnen	Verizon
Daniel	Menchaca	JIG (Spain)
Laura	Miexell	City of Pittsburgh, PA
Blake	Miller	Think Big Partners
Melissa	Miller	Greater KC Chamber of Commerce
Steve	Morgan	UPN Fiber
John	Muhlner	Sensity
Ayan	Mukhopadhyay	City of Nashville, TN
William	Mullins	UMKC
Dennis	Murphey	City of KCMO - SME
Meghan	Murphy-Houghton	National Science Foundation

First Name	Last Name	Organization
Kim	Nakahodo	City of Blue Springs, MO
Matthew	Newman	Oracle
Susan	Norris	ECCO Select
Kent	Nuss	Cisco Systems
Tammy	O'Bannon	Velociti
Angela	Orr	KC Area Development Council
Alex	Pazuchanics	City of Pittsburgh, PA
Mark	Petit	City of Summit, OH
Chelo	Picardal	City of Bellevue, WA
Michael	Pinkley	City of Branson, MO
Scott	Pomeroy	Downtown Council of Kansas City
Deryk	Powell	Velociti
Dean	Prochaska	USG (Firstnet)
Tony	Regier	Sirius Computer Solutions
Terri	Reintjes	Sprint
Sokwoo	Rhee	National Institute of Standards and Technology
Gordon	Rooney	City of Charleston, SC
David	Sandel	City of St. Louis, MO
Navya	Sane	
Hyeon-Shic	Shin	Morgan State University
Andy	Shirley	City of KCMO
Henry	Siegel	Ubicquia
Herb	Sih	Think Big Partners
Dean	Skidmore	
Sejun	Song	
Steve	Subar	Ubicquia
Fangzhou	Sun	City of Nashville, TN
Finn	Swingley	Here
Quest	Taylor	Pennez
Kenneth	Thompson	ch2m
Mark	Thurman	City of KCMO - SME
John	Tiefel	Sirius Computer Solutions
Norma	Tomsich	Mindteck
Rick	Usher	City of KCMO - SME
Vickie	Watson	City of KCMO - SME
Eric	Williams	
Brandon	York	
Tre	Zimmerman	Ubicquia