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MTI MINETA TRANSPORTATION INSTITUTE

A Framework for Integrating Transportation into Smart Cities

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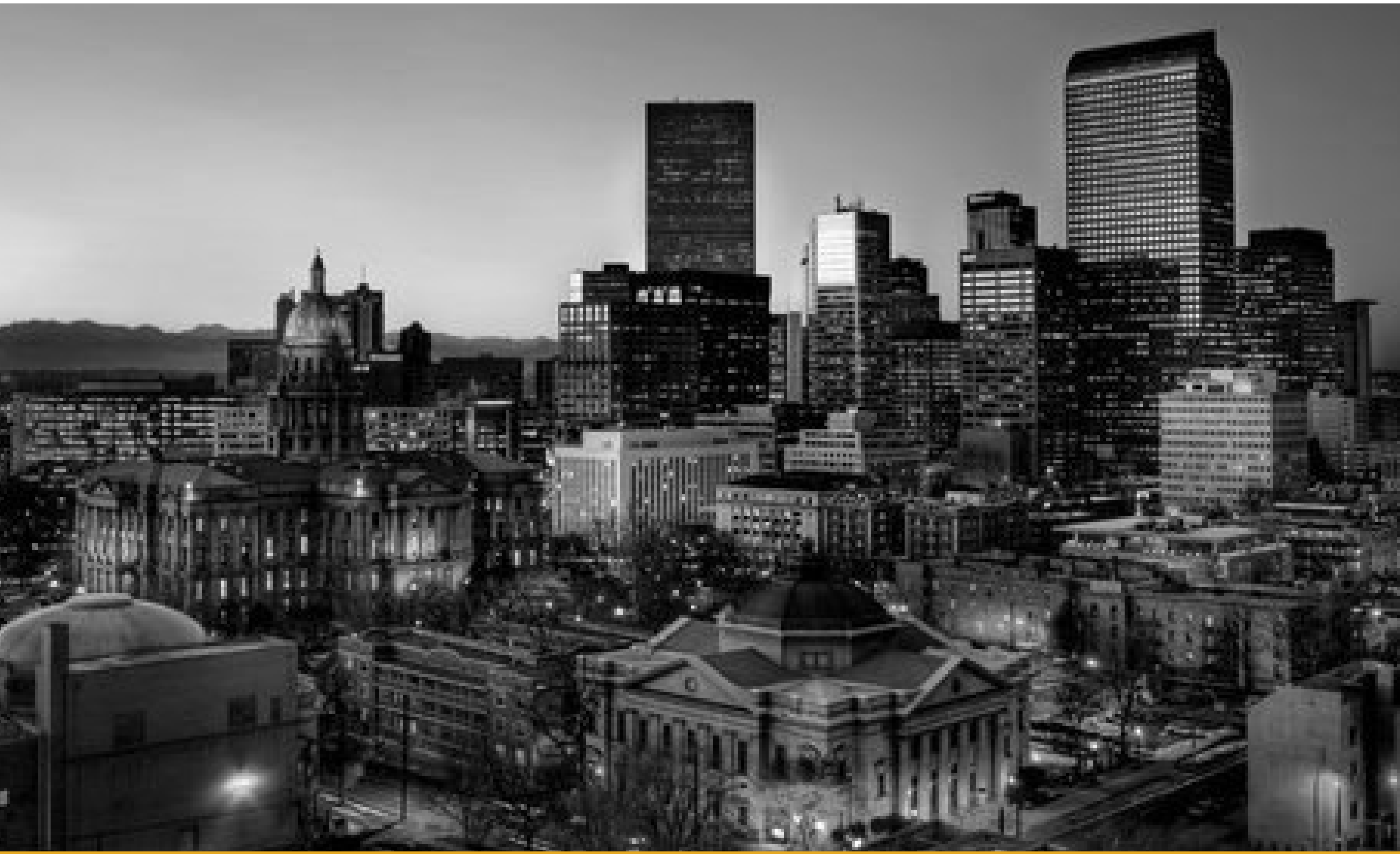

MINETA TRANSPORTATION INSTITUTE

LEAD UNIVERSITY OF
Mineta Consortium for Transportation Mobility

Founded in 1991, the Mineta Transportation Institute (MTI), an organized research and training unit in partnership with the Lucas College and Graduate School of Business at San José State University (SJSU), increases mobility for all by improving the safety, efficiency, accessibility, and convenience of our nation's transportation system. Through research, education, workforce development, and technology transfer, we help create a connected world. MTI leads the four-university Mineta Consortium for Transportation Mobility, a Tier 1 University Transportation Center funded by the U.S. Department of Transportation's Office of the Assistant Secretary for Research and Technology (OST-R), the California Department of Transportation (Caltrans), and by private grants and donations.

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REPORT 19-29

A FRAMEWORK FOR INTEGRATING TRANSPORTATION INTO SMART CITIES

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16. Abstract

In recent years, economic, environmental, and political forces have quickly given rise to "Smart Cities" -- an array of strategies that can transform transportation in cities. Using a multi-method approach to research and develop a framework for smart cities, this study provides a framework that can be employed to: (1) understand what a smart city is and how to replicate smart city successes; (2) the role of pilot projects, metrics, and evaluations to test, implement, and replicate strategies; and (3) understand the role of shared micromobility, big data, and other key issues impacting communities. This research provides recommendations for policy and professional practice as it relates to integrating transportation into smart cities.

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EXECUTIVE SUMMARY

Smart cities represent the convergence and strategic organization of innovation, digital technologies, and data in advancing the goals of environmental sustainability, economic development, equity, efficient service delivery, and enhanced quality of life for individuals and society. Smart cities advance innovations in public policy and administration, which foster collaboration and partnerships focused on people-oriented policies and practices.

In the United States (U.S.), the transport sector is the largest emitter of greenhouse gas (GHG) emissions. For this reason, smart cities have often been closely related to GHG reduction strategies and low-carbon, land-use, and transportation policies (U.S. Department of Transportation no date). As such, it is not uncommon for smart city concepts to emphasize transportation and technology deployments. In recent years, the concept of smart cities has grown rapidly as public agencies have been increasingly challenged to more intelligently and efficiently use resources in support of innovation, government efficiency, and environmental sustainability. While precise definitions of “smart city” vary, smart cities frequently leverage innovation and the use of big data and innovative mobility strategies to manage an ecosystem of civic resources including: transportation systems; telecommunications; utilities; health and human services; public safety; and other community services.

This report covers key findings on smart city practices and implementation in the U.S. Topics include: the role of big data and ways in which it is integral to smart cities; metrics for measuring the impacts of smart city implementation projects; and recent shared micromobility disruptions and responses, based on a case study analysis of 21 cities comprising the Smart Cities Lab.

A few key findings from the report include:

- The Pyramid of Innovation and Collaboration includes a region of collaborators and innovators working to advance seven domains: (1) smart energy and environment; (2) smart transportation; (3) smart governance; (4) smart workforce; (5) smart living; (6) smart economy; and (7) smart connections. This collaboration and innovation can be described as a pyramid of innovation that starts with the individual innovator and becomes progressively more advanced, culminating in increased regional innovation and multi-stakeholder collaboration.

- A “Planning, Pilot Implementation, and Evaluation” framework for smart cities allows communities to use a three-phase smart city process of planning, pilot implementation, and evaluation in order to understand key problems and foster collaboration. Phase 1 is comprised of an initial assessment, design-thinking workshops, and problem statement development aimed at understanding community concerns. This is followed by Phase 2, which includes a process of refinement and prioritization, as well as communities of practice, aimed at creating institutional capabilities in order to foster collaboration and pilot experimentation. Phase 3 is focused on pilot implementation and evaluation.

- A typology of four emerging smart cities and regions pursuing smart city initiatives can be mapped across four different smart city archetypes, including: (1) technology-oriented communities and regions driven by technological innovation; (2) economic-revival cities and regions reinventing their economies for post-industrial economic development; (3) growth cities and regions that are growing economically and spatially; and (4) small and rural communities investing in placemaking and workforce development for talent retention.

- Smart cities are about solving problems. Stakeholders must understand any given problem and how to identify challenges. Who is the problem trying to address? Why is it needed? How is the problem being handled at present? The problem-solving process is a critical ingredient to successful smart city outcomes. Stakeholders should focus on understanding the problems that need to be addressed before attempting to embrace policies and practices.

- Smart cities should be people-focused. Many well-meaning smart city initiatives have stumbled or failed because stakeholders have failed to engage with the communities impacted by potential implementation policies and programs. Rather than focusing on connected infrastructure, smart cities should focus on people-oriented outcomes such as walkability, bikeability, air quality, affordability, and citizen empowerment. In other words, cities should not focus on innovation and technology for its own sake, but on leveraging innovation and technology to improve community outcomes.

- Smart cities are about innovation. Innovation in management and the policy process is just as important as if not more important than technology. Public agency champions have to foster innovative management (both customer facing and internal) in order to create institutional capabilities to improve collaboration across organizational boundaries. This requires innovative organizational management and leadership. Additionally, policy innovation creates an enabling environment for policy experimentation, collaboration, and partnerships. There should also be a recognition that technology should not be viewed as a solution in its own right, but as an enabler for reducing inefficiencies and improving service delivery.

- Ensuring smart cities are equitable cities. There is an increasing concern that technology deployments may be leaving unbanked (households without access to a bank or credit card), underserved, and digitally impoverished (households without access to a smartphone or the Internet) communities behind. There is also worry that smart city practices may not be equitably serving all neighborhoods or economic strata, and that people with disabilities and other groups are being left behind. Finally, machine learning and artificial intelligence could be learning and then replicating inequities in society, reiterating historic biases and injustice. There is a need to ensure that smart city programs are accessible to everyone. The public sector has many roles ensuring equitable cities: as facilitator; as funder; as regulator; and evaluator of smart city initiatives. For example, these roles could include the facilitation of partnerships, the provision of subsidies and grants, and the development of proactive legislation and regulations to guide smart city initiatives toward equitable outcomes.

- Peer-to-Peer collaboration and the public-sector stakeholder engagement process revealed that there is a lot of interest in collaboration, identification of case studies and best practices, and development of an implementation strategy to solve a variety of challenges. Allowing public agencies to engage with each other in structured and non-structured environments, outside of the typical smart cities conference environment and not in the presence of private sector vendors, would result in the immediate benefit of being able to candidly share knowledge about what works and what does not with peers in other cities and public agencies.

- Breaking down silo barriers is critical. Organizational and departmental barriers stifle innovation and create inefficiencies. Breaking down organizational silos is needed to foster innovation, knowledge, and collaboration with an array of community stakeholders including: public agencies, non-profits, the private sector, and others. There has increasingly been a recognition of the need for partnerships, and a recognition that no one organization can do everything themselves. Similarly, the private sector has increasingly begun to recognize that partnerships provide opportunities.

- The term “smart cities” implies a focus only on the city, but our research reveals that the success of smart city initiatives depends on how the city engages with the larger region in finding and implementing policies and programs. Many of the challenges faced by typical urban environments are also faced by suburban and rural communities. For example, affordability issues and displacement in some communities are pushing the poor to the suburbs where there is also a need for smart city programs.

- Smart cities require omni-directional leadership vertically through an organization and laterally across agencies and stakeholder groups. This requires executive-level champions of innovation and staff that are empowered to support and carry initiatives forward. Additionally, distributed leadership across organizations is needed to foster partnerships and break down silos.

- Regional implementation of smart-city programs often varies by organizational structure, leadership, and champions. In all cases, strong leadership is needed to maximize smart-city opportunities. However, the forms of leadership and organizational structures involved in leading smart cities can vary notably (e.g., strong mayor vs. strong city manager; city-led vs. public transit agency-led vs. metropolitan planning organization-led initiatives; etc.). The presence of multiple champions encourages innovation, helps break down silos, and creates institutional resiliency that can transcend governance and staff changes.

- Big data and shared micromobility represent two notable challenges that smart cities are negotiating. The stakeholder engagement process revealed that smart cities’ interests in understanding and leveraging big data include: (1) identifying different data sources; (2) understanding how to manage data; (3) mitigating privacy concerns; and (4) initiating data projects (e.g., data agreements, data sharing, and data repositories). In addition to big data, shared micromobility (e.g., scooter sharing and bikesharing) emerged as another primary focus area, with smart cities’ concerns including: how to regulate it; how to ensure public safety; and how to incorporate it into the mobility ecosystem.

- Preparing the workforce for an automated future. There is a lot of concern that automation will displace jobs, and concern about the vast impact this will have on citizens and cities, including through impacts on employment and economic development. There is a desire for public agencies to proactively prepare for automation and leverage the potential positive impacts. There is also a recognition of the need for workforce development and for ensuring that training and job placement keeps up with automation.

- Smart cities vary by size and by region, as well as by economic, cultural, and other characteristics. Across the U.S., cultural attitudes toward public transportation, shared mobility, and urban density vary considerably.

I. INTRODUCTION

Smart cities signify the convergence and strategic organization of innovation, digital technologies, and data in advancing the goals of environmental sustainability, economic development, equity, efficient service delivery, and enhanced quality of life for individuals and society. Smart cities advance innovations in public policy and administration, which foster collaboration and partnerships focused on people-oriented implementations.

In recent years, technological, mobility-related, social, and demographic trends have been changing cities and the ways in which people live, work, travel, and consume goods and services. These trends have included:

- The growth of cloud computing, location-based navigation services, and mobile technologies;
- The emergence of affordability, gentrification, and displacement as significant challenges for many U.S. cities;
- The cross-cutting application of technology- and data-driven practices to overcome challenges in urban environments;
- The expansion of data collection, sharing, aggregation, and re-dissemination through crowd-sourced private- and public-sector sources that are facilitated through public-private partnerships, application programing interfaces (APIs), and other tools;
- The hiring of chief technology and data officers to help cities navigate these trends;
- The commodification of passenger services supporting app-based, on-demand transportation options;
- Increasing transportation demand and urban congestion, reduced transportation funding, and a need to maximize existing infrastructure capacity;
- Growing consumer interest in on-demand transportation options;
- An increasing demand for “instant gratification”, including for on-demand mobility, goods, and services;
- Demographic changes, such as rising life expectancy, rising retirement age, millennials entering the workforce, and rising rates of aging in place; and
- Growth in the percentage of the population embracing apps and other technologies.

In the United States (U.S.), the transportation sector is the largest emitter of greenhouse gas (GHG) emissions. For this reason, smart cities have often been closely related to GHG reduction strategies and low-carbon, land-use, and transportation policies. As such, it is not uncommon for smart city concepts to emphasize transportation and technology deployments. In recent years, the concept of smart cities has spread rapidly as public agencies have become increasingly challenged to more intelligently and efficiently use resources in support of innovation, government efficiency, and environmental sustainability. While precise definitions of what constitutes a "smart city" may vary, smart cities frequently leverage innovation and the use of big data and innovative mobility strategies to manage an ecosystem of civic resources including: transportation systems; telecommunications; utilities; health and human services; public safety; and other community services.

In 2011, the European Commission launched the "Smart Cities and Communities" initiative (SCC) providing €365 million in funding for energy, transportation, and information communications technology (ICT) innovations. The European innovation partnership on smart cities and communities (EIP-SCC) is an initiative supported by the European Commission that brings together cities, industry, small businesses, banks, research, and other stakeholders with the aim of improving urban living through more sustainable integrated programs and addressing city-specific challenges from different policy areas such as energy, mobility and transportation, and information communications technology. SCC engages the public, private sector, and other stakeholders in order to develop innovative programs and participate in city governance.

In December 2015, the U.S. Department of Transportation's (USDOT) launched the Smart City Challenge initiative in order to increase cities' focus on the use of integrated data, technology, and innovation as tools for solving stubborn urban challenges related to mobility. USDOT took a different approach to grant-making by awarding the entire $40 million to a single city rather than allocating this funding to multiple jurisdictions. The purpose of the challenge was to encourage cities to deploy these tools to plan for increased urbanization and growth that will put a significant strain on cities' capacity to deliver basic services. Paul Allen's Vulcan Inc. joined USDOT's Smart City Challenge by committing an additional $10 million to the winning city chosen through a USDOT selection process. The idea behind this approach was to encourage cities to develop proposals with smart city pilots and compete for funding proposed initiatives. Mid-sized cities were targeted for this competition as they were viewed as the cities with the greatest need technology pilots and implementation.

The USDOT funding was intended to stimulate partnerships among the public sector, major institutions, and the private sector in the form of committed funds, in-kind contributions, and administrative streamlining. The Smart City Challenge is a notable example of a partnership between federal, state, and local governments and the private sector intended to move forward the core vision of "mobility on demand" (i.e., the use of technology and data to help people and goods move more quickly, safely, efficiently, and economically). The vision of the Smart City Challenge was: (1) to demonstrate and evaluate an integrated approach to improving surface transportation performance within a city; and (2) to integrate surface transportation technologies with other aspects of public administration such as: first response; public services; and energy.

Eighty-one cities submitted 78 proposals for the USDOT's Smart City Challenge (a few cities were part of larger regional submissions) (see Figure 1 below). The 78 applicants faced a common set of urban mobility challenges and many proposed new approaches to solve these challenges. For example, 47 cities, including Atlanta and Las Vegas, proposed projects to test the use of automated shuttles to connect travelers to their destinations. Atlanta proposed a network of multimodal transportation centers serving as hubs for mobility, economic development, and community activity. Las Vegas proposed using connected automated shuttles to transport workers to Las Vegas Boulevard, as well as new solar powered electric vehicle charging stations that would help reduce emissions. Atlanta and Las Vegas are just two of many cities that included advanced traveler information systems and mobility hubs with shared mobility services. Two-thirds of the applicants proposed strategies to employ sensors and connected vehicles in order to collect data about travel by vehicles, bicycles, and pedestrians. Many Smart City Challenge applicants incorporated into their proposals advanced transit systems, smart parking information systems to facilitate urban deliveries, and carsharing services enabled through traveler information systems, digital kiosks, and smartphone apps.

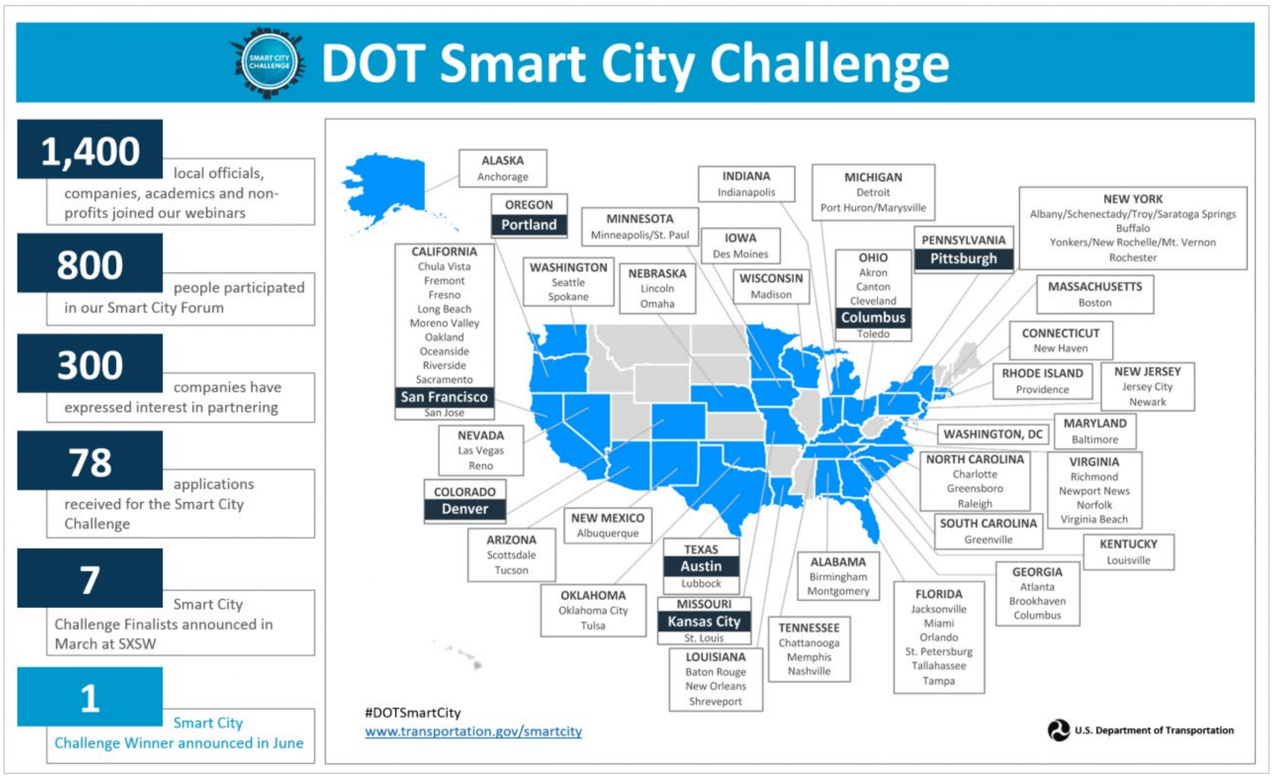

Figure 1. Smart City Challenge Submissions and Finalists

The Smart City Challenge produced seven finalists: Austin, Columbus, Denver, Kansas City, Pittsburgh, Portland, and San Francisco (highlighted in Figure 1). In the next phase of the challenge, the finalists worked to refine their proposals and USDOT encouraged them to collaborate with each other and share ideas. The finalists' public-private-partnership-driven proposals included a range of technological and administrative innovations to advance shared mobility implementation in urban areas.

The winner of the Smart City Challenge was Columbus, Ohio. Columbus offered an array of shared mobility strategies. Columbus' application focused specifically on increasing social equity and access to opportunity, by addressing infant mortality in the Linden neighborhood, where there were no OB/GYN service providers. Columbus proposed addressing infant mortality in this underserved community by using innovative technology to provide better access to pre- and post-natal care for women. Columbus also outlined plans for several other significant transportation innovations, including: an automated-vehicle test fleet that connects a public transit terminal to a job center; increased travel options in poor neighborhoods to better connect expectant mothers to health services; expansion of electric vehicle infrastructure; a multimodal transit pass payment system that includes public transit as well as pooled services (e.g., carpooling and transportation network companies (TNCs)); and kiosks that can reload public transit cards for low-income residents without credit cards or bank accounts.

The Smart City Challenge represents one of the first initiatives to advance understanding of smart cities and to recognizing how strategic partnerships among public sector agencies, institutions (e.g., community-based organizations, academia), and private sector technology providers can make cities more livable, efficient, environmentally sustainable, and equitable. All of the Smart City Challenge finalists also identified opportunities for leveraging technology to improve key quality-of-life metrics that extend beyond transportation. Some of these included initiatives to bridge the digital divide, fight crime, reduce unemployment, and increase the availability of affordable housing. In the future, the role of transportation planners will evolve and more frequently require an understanding of how smart city transportation investments can interface, impact, and be impacted by other aspects of urban planning and policy.

Together, the Smart City Challenge and other policies and programs have pushed visions of smart cities from the fringe to the mainstream, as cities across the U.S. have cultivated ideas for environmental sustainability, government efficiency, and integrated smart transportation systems that leverage innovation, data, and technology to help enhance quality of life in cities across the globe. As such, the definition of a smart city and the best ways in which to implement smart city principles have become a frequent topic of discussion.

REPORT ORGANIZATION

Section 1 of the report, this introduction, provides an introduction to smart cities and to this project. Section 2 provides a summary of the methods used to research and compile this report. In Section 3, the authors provide a background literature review on smart cities. Section 4 summarizes the findings of the expert interviews. Section 5 includes a discussion of big data and how it is integral to smart cities. Section 6 includes a three-phase framework for: (i) understanding the opportunities and challenges of smart city initiatives; (ii) creating institutional capabilities to foster inter- and intra- agency collaboration and experimentation-friendly environments; and (iii) implementing and evaluating pilot projects and strategies that focus on quality-of-life outcomes at three scales: neighborhood; city; and regional. Section 7 discusses the role of shared micromobility in cities today. Section 8, the conclusion, summarizes the key findings of the report.

II. METHODOLOGY

This study employed a multi-method approach to researching and developing a framework for smart cities. This approach employed five key methods:

1. Literature Review. The authors reviewed both North American and international literature on smart city strategies, and applied key findings from this review to inform the development of a smart cities framework for planning, implementing pilot projects, and evaluation. The authors supplemented the literature review with an Internet search of innovative and emerging trends supporting the growth of smart cities. Many of the online resources filled gaps in the literature where existing publications have not kept pace with emerging smart city practices and innovations. As part of this process, the authors identified and synthesized examples of smart city policies and practices. While the review was intended to be as comprehensive as possible, it remains possible that some smart city examples may have been missed.

2. Expert Interviews. Between Summer 2017 and Fall 2018, the authors developed an expert interview protocol and conducted two types of expert interviews. The first type, led by Mark Dowd's Smart Cities Lab (co-author of this report), entailed an intensive stakeholder engagement process with over 230 interviews, representing 58 public agencies across nine U.S. cities (Austin, Denver, Detroit, Kansas City, Omaha, Pittsburgh, Portland, San Francisco, and South Bend). The purpose of the interviews was to gain a deep understanding of each city, identify common themes, and gain an understanding of opportunities for each city to develop and implement pilot strategies. The **Smart Cities Lab** is a network of peer cities comprised of local public agencies that takes an experimental, open, and collaborative approach to collectively solving common problems related to mobility and equity.

As part of the expert interview process, the Smart Cities Lab spent at least one week in each of the nine cities, conducting approximately 30 stakeholder interviews organized by the Mayor's office in each city. Stakeholders included mayors, council members, transportation officials, local and community foundations, metropolitan planning organizations, utility companies, public health officials, community groups, universities, technology companies, automakers, and others. Each interview was conducted over 1–1.5 hours.

The second type of expert interview was targeted at stakeholder organizations engaged in smart city policymaking. These included: (1) the Climate Change Science Institute at Oak Ridge National Laboratory; (2) the Hewlett Foundation; (3) MetroLab Network; (4) the National Association of City Transportation Officials (NACTO); (5) the Natural Resources Defense Council (NRDC); (6) the Office of Energy Efficiency & Renewable Energy at the Department of Energy; (7) the Rand Corporation; and (8) the National Science Foundation. The purpose of the organizational interviews was to obtain expert perspectives on smart city concepts and on the characteristics that contribute to a smart city. Each of these eight interviews was approximately one hour in length.

1. Framework Development. Our smart city framework was developed based on the authors' experience with the 2016 US DOT Smart Cities Challenge (described in the

Introduction) and their collaborations with the Smart City Lab and the Texas Innovation Alliance throughout this project. The Smart Cities Lab is a peer city network, stitching together investments in innovative mobility across multiple cities into a single platform in order to work collectively to solve common challenges. The Texas Innovation Alliance is an action network of local, regional, and state agencies and research institutions who are committed to addressing community mobility challenges by creating a platform for innovation to leverage collective expertise, resources, and best practices. This report focuses on 21 cities, consisting of the Lab's initial nine cities and 12 Texas Innovation Alliance cities. This framework also draws upon the literature review; expert interviews; and a study of best practices, lessons learned, and key characteristics of smart cities. Smart city characteristics include: (1) mobility culture (e.g., auto-oriented vs. multimodal or public transit oriented, commute time to work, etc.); (2) the built environment (e.g., urban, suburban, edge city, etc.); and (3) socioeconomic factors (e.g., poverty level, household income, etc.).

2. Focus Areas Analysis. The authors identified two key focus areas for further review as part of this study: big data for smart cities, and dockless shared mobility. In 2018, dockless bikesharing and scooter sharing (also known as micromobility) emerged as a prominent issue in many cities, often with a number of large-scale dockless mobility services in their jurisdictions.

While this research approach to smart cities was extensive, encompassing a range of literature, experts, and case studies, it is important to note that smart city concepts and practices are rapidly evolving. Thus, it is possible potential literature, experts, and case studies may not have been included in this review.

III. BACKGROUND

The United Nation's forecasts that more than two-thirds of the world's population will live in cities by 2050. It is estimated that cities currently consume approximately 70% of the world's resources and are notable contributors of greenhouse gas (GHG) emissions and other environmental impacts. As such, the clustering of people, buildings, infrastructures, and resources often causes enormous strains on public infrastructure and the environment. Growing global trends toward urbanization, the growth of megaregions, and the need for environmental sustainability are causing cities to search for innovative ways to improve service delivery and mitigate environmental impacts.

One of the few points of consensus in the smart city literature is that the term "smart city" is ambiguous. Smart cities are difficult to define because "smart" cannot be defined for all contexts, and because cities are naturally complex. The foundational principles of smart cities are not new. The origins of smart cities can arguably be traced to the sustainable development and smart growth principles of the 1980s and 1990s. Common elements of these two development models include: open space preservation; historic preservation; development that discourages social inequity and socio-economic segregation; active transportation-friendly design; transit-oriented development; and compact mixed-use neighborhoods, often with the inclusion of recreational facilities and affordable housing. Although the precise details of these origins are unclear and not well documented in the literature, in the mid-1990s the American Planning Association launched "Growing Smart," a project that culminated in the *Growing Smart Legislative Guidebook: Model Statutes for Planning and the Management of Change* in 1997 (revised in 2002). In the same year, Maryland passed the Smart Growth and Neighborhood Conservation Act, a package of laws that supported smart growth policies. Also that same year, the Natural Resources Defense Council and the Surface Transportation Policy Project formed a smart growth program that promoted compact growth, mixed land uses, and transit-oriented development. Since then, smart growth programs have been promoted by a range of industry associations, non-profits, and special interests (e.g., Sierra Club, the National Association of Homebuilders, etc.).

Neirotti et al. have argued that the concept of a "smart city" is "a means to enhance the life quality of a citizen". However, in recent years a debate has emerged as to whether technology-based practices coupled with new approaches to urban planning are sufficient to constitute a "smart city". According to Bresnahan and Trajtenberg, the deployment of information and communications technology (ICT) should not be associated with the concept of smart cities, because smart initiatives entail not only technological changes but also investments in human capital and changes in urban living practices and condition. They argue that technology alone cannot improve livability or transform cities without human capital. Following this premise, a growing body of research in smart city development suggests that smart city technology investments also have to include local investments into human capital, such as: fostering capabilities for learning and innovation through education or job training, attracting and retaining highly-skilled professionals; securing long-term investments (financial and human capital) from innovative enterprises; and making it easier for investors and entrepreneurs with financial and human capital to launch new enterprises.

While there is no academic consensus on the definition of a smart city or its essential attributes, Ramaprasad et al. identified an extensible, scalable, context-adjustable definition framework that allows cities to be smart in different ways and to different degrees. The Department of Commerce's National Institute of Standards and Technology (NIST) defines the concept in their smart city framework as the "integration of data and digital technologies into a strategic approach to sustainability, citizen well-being, and economic development."

NIST's smart city framework encompasses nine categories: built environment; water and wastewater; waste; energy; transportation; education; health; socio-economic development; and emergency response. Each of these categories can be further subdivided into several data-producing facets. For example, transportation can be subdivided into travel demand, traffic management, and incident surveillance. The NIST definition focuses on the data-driven nature of the smart city and orients readers toward improving people's urban experience.

There is a vast literature on smart cities, with at least 36 different definitions of the term by one estimate. Several papers have attempted to create a systematic definition that encompasses the complexity of the smart city concept. These definitional papers may provide useful conceptual boundaries for the smart city concept, but NIST's definition is universal and standard, and thus preferable as a reference. While the academic literature lacks a common definition for the term, there appears to be a consensus on the domains of a smart city as established by Giffinger et. al.: smart economy, smart governance, smart mobility, smart environment, smart living, and smart workforce. These abstract domains provide a mental model for the complex, interconnected nature of cities. NIST's infrastructure-oriented domains are more useful for thinking about procurement and management of public resources. Different domain frameworks for cities should be viewed as complementary tools for gaining insight into sociotechnical problems, rather than as competitors or substitutes.

Many scholarly sources on smart cities assess progress toward achieving the "smart-sustainable city". Sustainability has its share of conceptual vagueness, much like smart cities, but it is generally understood to mean urban development that does not adversely impact the natural environment. The notion of a smart city as being an entity that would collect data introspectively on its own resource inputs and outputs, could play a key role in sustainable development.

Notable papers were selected based on their recent publication, comprehensive methodology, applicability to North America, and relevance of findings for policy design. Generally, the literature reviewed discussed smart cities in the following contexts:

<u>Big Data for Smart Cities</u>

- Transportation and big data
- Data ownership and privacy
- Security vulnerabilities with big data in urban management

- Overviews of hardware or software for realizing the smart city
- Data justice/equity

Smart-Eco City

- Particular focus on energy or resource consumption in a sustainable way
- Decarbonization or sustainability transport as a focus
- Smart disaster response or resilience
- Policy experimentation and living labs
- Ambient sensory factors ("sound analysis in smart cities")
- Case studies in resilience and shrinking (negative growth or degrowth) cities

Politics of the Smart City

- Ownership and equity of smart city infrastructure
- Participatory "co-creation" and equitable design of the smart city
- Urban governance and decision making
- Regionalism and the role of cities
- The role and need for metropolitan and regional governance and reimagining existing governance frameworks
- Criticism of the smart city concept as a framework for equitable or sustainable development

Urban-Rural Interface

- Relationships between urban and rural technological development
- How to integrate rural areas in support of regional sustainability
- The benefits of ICT in small cities (populations less than 100,000)
- "Smart village" concept originating in Europe (potential relevance for smaller North American municipalities)

<u>Smart Transit</u>

- Equity considerations in public transit planning in cities that have implemented smart transit policies

- The feasibility of automated vehicles and automated transportation systems

<u>Frameworks and Assessments</u>

- Equity frameworks and smart cities

- Quality of life metrics as a framework for analyzing smart cities

- Sustainability metrics for analyzing smart cities

For the purposes of this literature review, the authors focused primarily on journals and reports documenting frameworks and methods for assessing smart cities. Kamruzzaman et al. identified criteria to assess social exclusion disadvantage measures in transportation. The criteria can be broadly grouped into three categories: (1) spatial (e.g., urban accessibility and public transport accessibility); (2) temporal (e.g., public transport availability and facility opening hours); and (3) social attributes of travel and activity participation (e.g., personal mobility and disability). Similarly, Shaheen et al. developed the STEPS framework, which includes: spatial, temporal, economic, physiological, and social measures for assessing equity in transportation that could also be applied to the smart city context.

A few frameworks disagree on the relative role and importance of technology-related indicators versus sustainability, equity, innovation, and other considerations. One framework identifies spatial, socio-economic, supply, satisfaction, and strive indicators, referred to as 5S. Escolar et al. proposes a ratings-based approach for smart city comparisons to evaluate the strategic decisions taken by cities. They concluded that current city rankings typically omit ICT-related indicators; as such, they propose technological criteria for designing smart city rankings and applies this methodology to compare New York, Seoul, and Santander. In contrast, Lopez-Carreiro and Monzon examine smart urban mobility and propose a smart mobility index incorporating sustainability and innovation principles. Ahvenniemi et al. analyze 16 sets of city assessment frameworks (eight smart city and eight urban sustainability assessment frameworks) comprising 958 indicators in three impact categories and 12 sectors, and found that these frameworks tended to have a stronger focus on technology than on sustainability. They argue that smart city frameworks lack environmental indicators while highlighting social and economic aspects. They recommend using the term “smart sustainable cities” and incorporating environmental, economic, and social sustainability indicators and redefining the overall smart city narrative. Similarly, Artmann et al. also argue for the need to incorporate smart growth concepts, green infrastructure, smart environment, and governance into a systematic smart cities framework.

Debnath et al. use a benchmark assessment with numeric scores to measure levels of “smartness.” They suggest two levels of “smartness:” (1) “basic smart,” involving four key characteristics: sensing/monitoring; processing; acting/control; and communicating; and

(2) “advanced/higher order smart,” with three key characteristics: predicting; healing; and preventing. They conclude that some cities have properties that reflect both the basic and advanced levels of smartness. Cavalcanti et al. suggest an Urban Mobility Project Sustainability Index (UMPSI) that considers environmental, social, and economic aspects of smart cities at a project implementation level. The proposed method consists of 17 sustainability indicators, grouped according to their connection with these three categories. Another framework uses a case study method to argue that institutions (e.g., non-profits, universities, and associations) contribute to a city’s “smartness” because they support inclusive and informed decision-making processes. Other researchers highlight the need for a framework that incorporates environmental justice considerations into smart city and transportation decision-making processes.

Other research emphasize the need for real-time information for feedback response. Marsal-Llacuna et al. highlight the need for real-time indicators to develop and monitor a smart cities index.

SUMMARY

Key takeaways from this chapter include the following:

- The term “smart city” is ambiguous; there is no academic consensus on its meaning.
- Environmental and smart growth urban development models, which favor compact transit-oriented cities, are considered the conceptual foundation for smart city development.
- NIST defines smart cities as the “integration of data and digital technologies into a strategic approach to sustainability, citizen well-being, and economic development.”
- There appears to be an academic consensus on the domains of the smart city as established by Giffinger et. al.: smart economy, smart governance, smart mobility, smart environment, smart living, and smart workforce. These domains represent different aspects of urban and human capital development.
- Many scholarly sources on smart cities assess progress toward achieving the “smart-sustainable” city concept, which combines ideas from ICT and sustainable development.
- The literature review conducted for this report identified six categories of smart city research: big data; smart-eco cities; politics of the smart city; smart transit; urban-rural interface; and frameworks and assessments.
- A few frameworks for analyzing existing global smart city development disagree on the role and importance of technology-related indicators versus indicators of sustainability, equity, innovation, and other considerations. Emphasis on a particular aspect of development, such as technology or sustainability, changes the overall smart city narrative.

- Smart city assessments have used benchmarks, indicators, and case study methods to determine the extent to which cities have achieved their "smart" aspirations for improving urban living.

The next chapter reviews expert insights into how they define smart cities, key characteristics of smart cities, and recommendations for public agencies developing a smart city strategy.

IV. EXPERT INTERVIEWS

To help define the term “smart cities” and develop a conceptual framework to integrate transportation into smart city design, the authors conducted seven targeted expert interviews representing different organizations during the period of January to March 2018 to better understand key elements of smart cities. Experts were recruited for a 30- to 60-minute interview based on their professional role or their organization’s role in urban policy, big data, technology, and smart cities. Interviewees are represented by the following agencies:

- The Climate Change Science Institute, Oak Ridge National Laboratory
- The Hewlett Foundation
- MetroLab Network
- The National Association of City Transportation Officials (NACTO)
- The National Science Foundation (NSF)
- The Natural Resources Defense Council (NRDC)
- The Office of Energy Efficiency and Renewable Energy (EERE)
- The Rand Corporation.

GENERAL PERCEPTIONS OF SMART CITIES

During the expert interviews, we asked questions that probed existing knowledge, lessons learned, and best practices for creating a smart city. Questions included a variety of topics such as: general perceptions of how an expert envisioned their ideal smart city and planning considerations for smart city initiatives. Typically, the concept of a “smart city” emphasizes the use of data and technology to optimize a city’s management and efficiency. However, current smart cities perceptions, based on our expert interviews, encompassed broader socio-technical and socio-cultural views and also focused on a city’s community. Topics discussed included social issues, such as affordable housing and automated vehicle access, as well as more data-related issues, such as cybersecurity and data privacy.

Some key questions included:

- “How do you define a smart city?”
- “What are the components of a smart city (e.g., smart living and smart mobility, as defined in Giffinger et al.’s smart city framework)?”
- “What do you think are the greatest opportunities and challenges of smart cities in your region?”

- "What outcomes do you expect for the short term of smart city development and in the longer term?"

- "What recommendations do you have for cities/public agencies who are developing a smart city strategy?"

Interviews began by asking experts how they define the term "smart city." While there were some negative perceptions about the term, others had positive impressions. Most experts interviewed agreed that the term was vague, often misinterpreted, and sometimes misused for commercial purposes. Some experts rejected the term entirely, saying that "smart cities" lacked definition and was over commercialized, often by technology vendors. Those who criticized the term referred to it as being "artificial," "meaningless," and a "marketing tactic" rather than a meaningful concept to guide a city's efficiency or potential for innovation. Other experts, however, embraced the term, citing opportunities for incorporating technology into the urban environment. Those who reacted positively provided examples of how technology could improve the built environment. Common opportunities identified included improving transportation system efficiency, fostering public-private partnerships, and leveraging technology to maximize infrastructure capacity and improve municipal service delivery.

Experts were asked if smart city concepts could address current municipal challenges in the areas of service delivery, management, and social equity. Some interviewees were concerned that cities would prioritize smart city programs' focus on technological applications at the expense of service delivery and quality of life programs, such as resources for the homeless, affordable housing, and other often underfunded programs.

Several experts noted that one challenge city governments are confronting is a fundamental change in urban growth patterns due to changes in consumer technology (e.g., smartphones, telework). In recent years, consumption choice has shifted to digital services and goods delivery, replacing in-person trips. One expert noted that cities were once built around large physical developments, such as a main street filled with theaters and shopping malls. Today, these physical features are being redefined and, in some cases, replaced by IT-based functions such as digital media and online shopping. Several experts indicated that cities are a legal construct, defined by geography, place, and space, but that they are also socioeconomic constructs (e.g., cities are being impacted by cultural activities, and retail services are being redefined by technology).

One expert stated that the ideal smart city is one that does not require cars. This expert suggested a holistic approach, developing a smart city framework with metrics accounting for non-single occupant vehicle access and active transportation options. These car-free or car-light options are often absent from many smart city discussions. Many experts said that most cities, particularly smaller and growing urban areas, may not have the capacity to transform their infrastructure due to external factors, such as their political environment or conflicting community values.

Based on the expert interviews and Giffinger's smart city components (defined on page 12), we selected the following terms as a general categorization for smart city components:

community members; economy; smart mobility; smart infrastructure; environment; smart living; and smart governance. Taking these categories into consideration, the expert interviews allowed us to determine which elements of these categories were most important. The following section summarizes the interviews in terms of a five-category framework for key components of a model smart city, encompassing ideas presented from experts in the fields of planning, transportation, and engineering:

- Information and Communication Technology (ICT) and Big Data: Using analytical tools to gather, analyze, respond to data and trends;
- Management and Public Policy: Leveraging smart city concepts and developing policies to more effectively manage governments through a culture of innovation;
- Public-Private Partnerships: Partnering with the private sector, typically to collect data or create more efficient infrastructure. Research institutions and non-profits are also viable partners;
- Equity: Ensuring fair access to city resources and opportunities for employment to underrepresented and disadvantaged community members; and
- Livability and Sustainability: Measuring individuals' and cities' general well-being and livability using a variety of metrics (e.g., air quality, crime, healthcare access, travel time to work).

INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) AND BIG DATA

Experts generally agreed that there is an abundance of data and tools available for supporting a smart city strategy. However, these data and tools may be proprietary, closed source, non-standard, or in formats that make inter-agency technology transfer difficult. Experts provided examples of private companies, such as transportation network companies (TNCs, also known as ridesourcing and ride-hailing companies), that obtain large volumes of route data, but prevent municipal agencies from using that data for improvements. When data are privately owned, municipal use is not guaranteed. One expert said that sharing anonymized data through a third party is a preferred best practice. All experts emphasized the role of technology and of making data-driven decisions in support of effective regional planning.

Experts suggested that there is a need to create a secure space to share data, while still protecting individual privacy, to optimize municipal services. There are a variety of reasons for difficulty in data collection and processing, and a common data repository could improve overall data quality and availability. Some key challenges identified in this area included: inaccurate data due to some surveys disproportionately reaching certain demographics; privacy protection for individual users; and large quantities of non-shareable proprietary data stored by private companies providing mobility services. One expert noted that data are available in ever greater quantities, since individuals are also independently collecting personal data through technologies such as Fitbit, Google Maps, and Amazon Alexa, among others. There is no standardized procedure for collecting individual user data in a way that is useful to regional and municipal planning, nor is there a standardized way to anonymize or protect these data.

One expert explained how a “smart government” could have two of its core departments, operations and planning, make decisions based on real-time data. The types of data they would collect and analyze would be different. The planning department would collect data from sensors on noise, air quality, and other ambient conditions. Operations would collect data from streetlights, water lines, and other local infrastructure. Both departments would be able to share data as needed in order to complete projects and conduct preventive maintenance.

One expert noted the importance of recognizing how historical biases may become embedded in and reproduced by a smart city strategy, stating that it “behooves planners to value human rights as fundamental to any technological development strategy.” This expert went on to say that implementing technology in a socially equitable way should be a city government’s responsibility, while cybersecurity and high-level algorithmic data processing should be considered a state or federal responsibility.

MANAGEMENT AND PUBLIC POLICY

Experts generally held similar views to each other on leveraging smart city concepts effectively to improve municipal service efficiency and quality of life. Many experts emphasized the concept of “horizontal planning,” or coordinated planning and communication across different sectors (i.e., public works, planning, traffic enforcement, local city council members, etc.). Experts also said that smart city applications should be uniquely tailored to the size and growth pattern appropriate to a given city. A smart city application should behave differently for a city that has reached full build-out versus a city that is still growing.

One aspect of city management that all experts agreed upon was the necessity of regional planning. Communication between cities on regional initiatives was considered a top priority in almost all expert interviews. Regional Metropolitan Planning Organizations (MPOs) and other public works-oriented agencies, such as the San Francisco Bay Area’s Metropolitan Transportation Commission, would continue to be influential with municipal planning and public works departments. Experts suggested short-term changes, particularly increased inter-agency transparency, in order to improve regional planning. Creating more transparent and communicative institutions across urban scales was highly valued among experts.

One of the main points that experts identified was the impact of politics as an institutional barrier to innovation and decision making within a city. One expert emphasized the importance of “smart governance,” and that “smart” should not be exclusively branded for technological progress, but rather applied to initiatives in management, institutional operations, leadership, and community representation within public processes.

In addition to management innovation, some experts also discussed opportunities for transformative public policies that represent both institutional and technological innovation. One expert discussed a new kind of incentive system aimed at decreasing automobile use. In this expert's example, civilians would be paid to use active transportation (i.e., walking and biking) and/or higher occupancy modes (i.e., buses and light rails) in order to decrease traffic congestion and improve quality of life metrics. This approach would constitute a feebate-type policy for reducing private or single-occupant vehicle usage. Policy development could take place around various stakeholders, public-private partnerships, or public-research institutional partnerships that would then spur innovation in other sectors.

THE ROLE OF LEADERSHIP, CHAMPIONS, STAKEHOLDERS, AND PUBLIC-PRIVATE PARTNERSHIPS

The experts interviewed talked about the importance of strong leaders and champions across regional stakeholders that have mutual interests and synergies in smart city policies and programs. While the experts interviewed emphasized variations in smart city implementation based on organizational structure (e.g., strong mayor vs. city manager), strong leadership and champions were identified as a common theme across smart city initiatives. Additionally, experts emphasized the need for champions representing multiple stakeholders to help break down organizational silos and ensure continuity of smart city initiatives through personnel changes (e.g., a new mayor, new agency staff, etc.). Experts said that having multiple champions representing a diverse stakeholder group helps build institutional resiliency into smart city programs over time.

Additionally, many of the experts interviewed mentioned the opportunity cities have for leveraging public-private partnerships. Many experts gave an example framing these partnerships in terms of transportation services managing big data collected by a municipality. Many experts also highlighted opportunities for the private sector to encourage sustainability and active lifestyles through partnerships aimed at data sharing, transit-oriented development, joint design of transit and mobility hubs, and other collaborative opportunities. Many experts focused on contemporary examples of public-private partnerships that link government-authorized bikesharing or carsharing initiatives integrated with private companies through mobile device applications. Public-private transportation partnerships can benefit financially by improving rider service, while the data they generate could be used by public organizations. Coordination between the public and private sectors would ideally create a more efficient private service, while improving core public infrastructure in the city.

Partnerships between city governments and local universities and other research institutions on smart city initiatives can also offer mutual benefit. One expert provided the example of a city that was leveraging the expertise of a community research institution to conduct workforce development for smart city software and automation, to perform real-world tests of big data management and analytics techniques, and to collaborate on the transfer of completed smart city applications.

EQUITY

Experts generally indicated that a "smart city" ought to be a city that is "equitable" and "livable," not just efficient. Many experts upheld the importance of equitable urban development from a variety of perspectives, including transportation, housing, and community engagement.

Equitable transportation was a frequent topic of discussion among the experts. One expert quoted Fred Kent, the founder of Project for Public Spaces, who wrote that “if you plan cities for cars and traffic, you get cars and traffic. If you plan for people and places, you get people and places,” to illustrate the importance of planning for equitable mobility in cities. Other experts agreed that extant roadway networks are designed around private vehicles, but that “smart planning” should reduce, and potentially prevent, the widening societal gaps between “haves” who are able to use automated-vehicle or for-hire-vehicle services, and mobility-limited “have nots.” One expert raised the possibility of a smart city addressing specific equity needs, such as by providing specialized transportation for children of single parents, so their children can access after-school programs during the work day.

One expert emphasized that streets primarily serve cars, not people. This expert emphasized the importance of policymakers’ focusing on urban active transportation safety. Ideally, policymakers should consider making walking and cycling more accessible to the public as a core social equity strategy. This expert suggested leveraging data-driven smart city applications to identify traffic safety projects to achieve “Vision Zero” goals—the elimination of pedestrian and cyclist accidents and fatalities. Many cities in the United States, such as Portland and New York, have joined the multi-national Vision Zero project to strive for a road network with no fatalities or serious injuries.

In addition to transportation safety, most experts established a direct link between smart cities, transportation equity, and affordable housing. These experts indicated that a smart city is one that has an affordable jobs and housing balance (i.e., affordable housing located near jobs), emphasizing the importance of providing affordable housing and planning for affordable transit-oriented development at mobility hubs. Additionally, most experts expressed the importance of community engagement, emphasizing broad participation and a process for building trust and listening to neighborhood concerns during “smart” strategy development. Inconvenient meeting times and locations were cited as being among the barriers to a deliberative process. When asked about best practices for community engagement in a smart city, the experts cautioned against survey-driven policy development, since surveys are prone to having disproportionate responses among specific socio-demographics.

LIVABILITY AND SUSTAINABILITY

While the expert interviews primarily focused on equity, big data, and the role of public-private partnerships, a number of experts also discussed improving public health and the role of sustainability technology. Many experts reinforced the importance of including quality-of-life components in the definition of smart cities rather than using a primarily innovation- or technology-focused definition. These experts emphasized active transportation indicators for quality of life, such as walkability. The ongoing need to correct market failures through policies such as congestion pricing and affordable housing, were also underscored. Infrastructure-monitoring technologies could play a crucial role in connecting quality-of-life data with real-time management of urban transportation. One expert suggested that planners should embrace the integration of information technology with physical infrastructure as part of the planning process (e.g., real-time traffic signal controls aimed at reducing congestion and increasing active transportation modes). Finally, one expert emphasized a holistic policy approach for long-term planning toward sustainability by balancing transportation system congestion, workforce size, environmental impacts, system monitoring capacity, and system maintenance.

SUMMARY

The expert interviews revealed the following key recommendations:

- Smart city plans and policies are best developed through inter-department and inter-agency collaboration and communication.
- Public-private partnerships based on data sharing, technology transfer, and progress toward sustainability targets should be beneficial to most community members by improving a city's core public infrastructure.
- Quality-of-life metrics for community members must be central to a strategic framework for smart city development.
- Local institutions and organizations (e.g., community colleges, universities) can be valuable partners in smart city initiatives by providing opportunities for applied research, data analysis and management, workforce development, and technology transfer.
- Effective community engagement must be part of the planning process for smart city policies.
- Transportation data generated by the public sector, the private sector, and pedestrians should be directed toward an improved experience of public transit and physically active travel modes.

V. BIG DATA AND SMART CITIES

The rapid expansion of intelligent transportation systems, location-based services, and wireless and cloud technologies, together with real-time data, is contributing to the growth of smart cities. Big data is commonly considered a critical component of a smart city. In 2016, the American Planning Association (APA) proclaimed that big data "will transform the practice of planning" for cities. Smart city policies are commonly driven by big data to improve quality of life and economic productivity.

BIG DATA AND ITS RELEVANCE TO SMART CITIES

For public agencies, data becomes "big" when the data cannot be conveniently analyzed by traditional statistical methods or common software tools. Big data is causing a shift in institutional thinking about how data are shared and used. Rather than thinking of big data only in terms of the size and number of datasets, big data should be seen as reflecting "[a] new attitude by businesses, non-profits, government agencies, and individuals that combining data from multiple sources could lead to better decisions." The use of big data requires prudent public policies to govern data sharing (for public and private sector partners) as well as open access that is coupled with privacy protections for individuals and trade secrets.

Public agencies commonly use big data for identifying transportation safety trends with spatial (location-based) precision to prevent accidents and fatalities and improving municipal service delivery (e.g., public transit routing, city tree care, and predictive selection of child welfare cases), among other improvements to critical public works and policing services.

Effectively using big data in policy design is essential to developing policies and initiatives for smart cities. However, using big data alone to guide policy does not make a city "smart," since the social implications also should be considered.

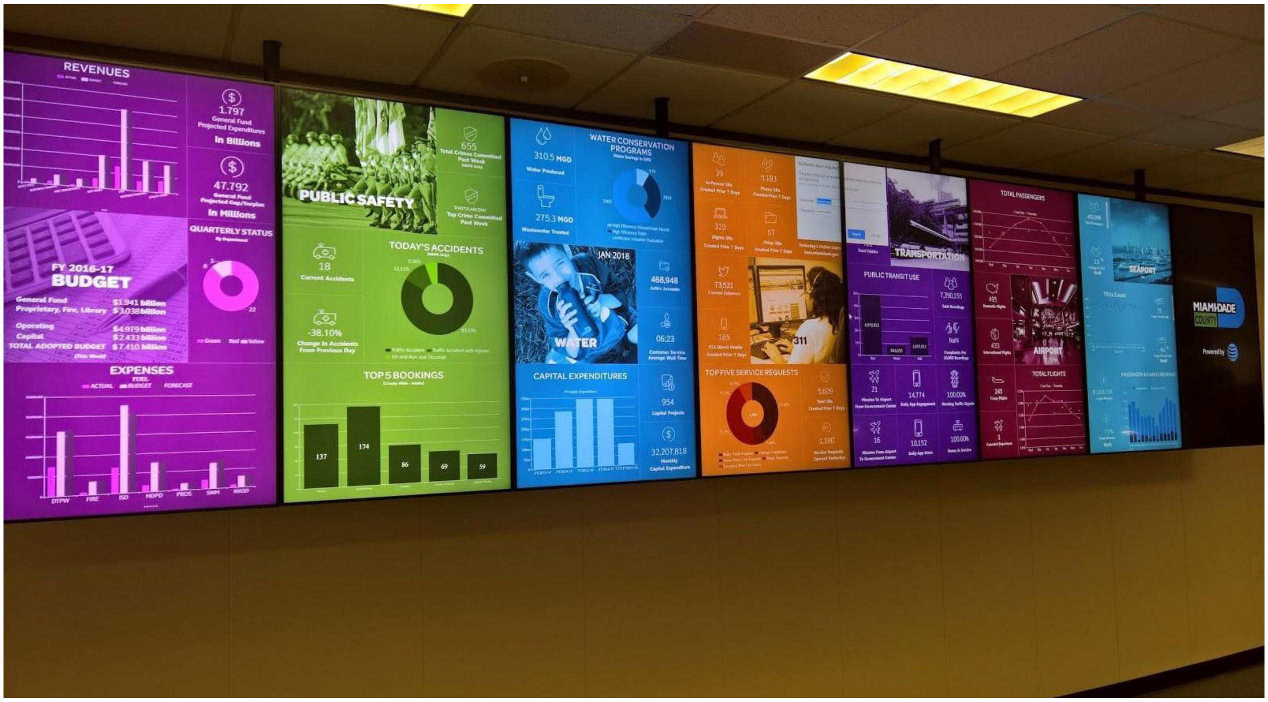

Figure 2. Miami's Smart City Operations Center

Source: Photo by Adam Cohen

The City of Miami uses big data to monitor core municipal functions. This visual display in the Mayor's Office summarizes vital statistics as part of AT&T's Smart Cities Operation Center. AT&T was contracted to provide several critical transportation and public safety-related services, such as LED lighting upgrades to the city's street light grid and real-time data monitoring of noise, air quality, traffic, and other key metrics.

BIG DATA ENABLERS IN SMART CITIES

A review of technologies involved in the development of smart cities identified four key enablers of big data generation and analysis in smart cities:

- *Cloud Computing*: This entails sophisticated computing power capable of processing big data in real time and storing vast amounts of data. As a best practice, municipalities should check with a potential public cloud provider that their data can be retrieved in a usable format at any time at a reasonable cost on demand. Cloud computing-scale data processing allows public agencies to detect patterns in data sets that may not have been apparent through manual inspection by staff. There are notable ethical implications when computing systems operating over large data sets inform public policy decisions.
    - State and city governments have been transitioning to cloud-based infrastructure for their information technology systems following the 2011 Cloud First policy released by the federal government. For example, in 2011, Colorado's Office of Information Technology released the state's "Cloud Strategy" report. As part of the state's strategy, cloud services would be

adopted by default rather than deploying and maintaining extensive server infrastructure.In 2018, the federal government adopted a Cloud Smart policy that attempts to correct shortcomings in the Cloud First guidance by unifying cybersecurity, procurement, and workforce capability into a single process.

- *Internet of Things (IoT)*: Networks of smart objects (e.g., automated vehicles, home thermostats, industrial machinery) communicating their state to each other to achieve gains in energy efficiency and prevent crashes or unexpected outages. IoT provides a way for local agencies to access real-time information on resource consumption (i.e., energy and water); environmental quality (i.e., air pollution); and transportation network performance (i.e., congestion) among other things. Cybersecurity becomes a greater public risk as more municipal infrastructure becomes networked, and therefore, at risk to hijacking or collapse through hacking.

    - One notable IoT deployment is Chicago's Array of Things. In 2016, Chicago, in partnership with the University of Chicago and local high schools, launched a project called Array of Things to create a network of sensors on public infrastructure that measures ambient attributes such as: noise, temperature, and particulate matter. The city operates around 200 sensor groups at intersections across the city. Data generated by Array of Things is available through the city's open data portal.

- *Open Data*: This is information made freely accessible for more transparent governance, which provides the opportunity for people to contribute to urban development. Cities must balance transparent governance through open data, with public records protections that ensure privacy for individuals and private sector partners.

    - In Washington D.C., the district offers a wide variety of open data, including data related to transportation and road infrastructure, much of it available in a geographic information system accessible format. Open source tools for developers to create their own applications using D.C.'s open data are also available.

- *Smartphones, wearable devices, and smart appliances*: These are personal devices that generate information about the user's activities and act as a bridge between people and data-driven services. At a city or regional level, the collected data from these devices can produce snapshots of urban activity, such as energy consumption or transportation patterns. Unless properly secured and anonymized, data generated from smartphones, wearable devices, and smart appliances may be used to identify and target individuals.

    - Smartphones are creating new possibilities for personal transportation and goods delivery. Dockless micromobility and TNC services are typically accessed through smartphones. The big data generated through the use of innovative transportation services are relevant to transportation planning initiatives.

These enabling technologies of big data have resulted in more data-driven services and informed public sector decision making. Not surprisingly, a number of public policy issues have arisen as a result.

COMMON TOPICS OF PUBLIC POLICY CONCERN

Big data have the potential to make government more efficient and responsive. However, the use of big data can also present a number of risks for the public sector. Four common topics of public policy concern and response are as follows:

- *Protecting Privacy Through Anonymized Data:* People commonly use apps and digital services because they trust that these services will deliver what is promised, and this trust extends to perceived security and comfort in using a service. Public agencies offering services through apps and digital platforms are expected to protect the identity of private citizens through the use of anonymized data and the use of best practices to prevent the identification of individuals by triangulation from several pieces of anonymized data. Public agencies contracting with private developers can specify limits to data collection within a digital service. As a best practice, cities can also help to protect user privacy by developing a data privacy policy that includes information on how data are collected and used, how long they are retained, and how the data may be shared. In June 2018, the California state legislature passed AB 375, a landmark piece of data privacy legislation, which will affect smart city services, as well as familiar online services like Facebook, that collect data about their users. The law, which goes into effect on January 1, 2020, is likely to become the national standard for data privacy and establish the monetary value of user data.

- *Cybersecurity:* Cybersecurity refers to the organizational capability to prevent, detect, and respond to attacks on information technology systems. Public agencies should take hacking and data vulnerability seriously. Ensuring that data use adheres to standard and disclosed policies is key to a smart city big data strategy. Municipalities may be exposed to risk when they rely on big data without adequate cybersecurity insurance or third-party data protection (e.g., by Microsoft or Amazon). Common risk mitigation measures may include data security, insurance, and operational contingency plans in the event that a data theft, breach, or ransom occurs.

- *Public Records Protection:* Data used by a public agency may be subject to public records requests, whether internally or externally sourced. This poses a challenge to governments seeking to protect the privacy of their residents or the trade agreements of their private partners. Public agencies should comply with these requests by ensuring personal identifiable information has been anonymized. State and local governments should consider reforming privacy laws to protect personal identifiable information and trade secrets. At a minimum, municipalities should have data storage and retention policies in place to preserve records in the event of future records requests or litigation. A 2018 Yale Journal of Law and Technology article has suggested that public entity contracts should require vendors to create and deliver public records that explain their data policy decisions and validation efforts in a way that upholds their trade secrets, so transparency does not have to be sacrificed in private-sector partnerships.

- *Ethical Regulation of Machine Intelligence:* Machine intelligence systems depend on data to make decisions, but data collection and algorithm design (computer-automated logical rules) can over-target certain groups of people or only function correctly in some locations or for certain groups of people. Over-targeting is called "algorithmic bias." Machine intelligence software can entail issues of bias or fairness. This can be curbed by involving people that are aware of the wider social context of machine learning and recognize the value of transparency in its inputs and procedures. To aid ethical decision-making involving machine learning (e.g., public safety, long-term infrastructure planning), algorithms should be "interpretable" and transparent rather than kept secret. While there are no established best practices for the development of ethical policy for the use and management of big data as it applies to machine intelligence, technical best practices for the implementation of ethical big data-based software systems are currently being developed.

Naturally, the public sector will contend with policy issues surrounding big data involved in innovative policies and programs. In 2016, the APA developed a generalized framework for communities considering big data-driven policymaking.

BIG DATA-DRIVEN POLICYMAKING FRAMEWORK: STRUCTURE AND BEST PRACTICES

Desouza and Smith developed a four-phase knowledge-management framework for municipalities that are developing their first smart city policies or considering the adoption of smart city interventions in the future. Phase 1 has been added to Desouza and Smith's original framework (Phase 2 through Phase 5) to highlight the importance of understanding the problem to be solved before organizing or collecting data. This framework is intended to solve specific municipal problems rather than outline a comprehensive smart city strategy.

- Phase 1 - *Define the problem*: Determine whether big data methods are appropriate for understanding or solving the problem. Big data can be helpful in describing averages or trends; however, it can also raise ethical and privacy concerns related to data sources and management.

- Phase 2 - *Collect data:* Gather data that may be relevant to the problem and determine its accuracy. Data may need to be protected or anonymized.

- Phase 3 - *Perform analyses:* Prepare data for an analysis through a process of correcting irregularities or mistakes (e.g., inconsistent labeling, erroneous associations between cells). Develop an appropriate analytical method to identify data patterns that may not otherwise be evident through a manual data analysis. Communities of practice or data scientists associated with local research institutions may provide technical expertise for model design or implementation. Reuse and sharing of analytic models for common municipal problems is a best practice.

- Phase 4 - *Seek feedback:* Examine potential issues, such as ethical implications of the analysis or ramifications of the analysis for existing policies, when reviewing analytical outcomes. Internal and third-party experts can help to identify potential bias in the results. Seek public comment along with expert input if the problem impacts the public directly.

- Phase 5 - *Evaluate policy:* Assess policy outcomes and adjust policy based on real data in the next iteration of policy design, as appropriate. Build institutional capacity for ongoing refinement of big data analytical activities.

SUMMARY

Key takeaways from this chapter include:

- "Big data" is a field focused on analyzing any amount of data that cannot be analyzed by traditional statistical methods or common software tools. The goal of integrating big data into urban development is to make predictions, design more realistic policy scenarios, and make real-time interventions that enable cities to be more responsive, sustainable, and resilient.

- There are four primary "enablers" of big data that are crucial to the development of smart cities: (1) personal devices (smartphones, wearable devices, smart appliances); (2) the Internet of Things (IoT); (3) open data; and (4) cloud computing.

- There are numerous public policy implications related to big data including: (1) the importance of protecting individual privacy through anonymized data; (2) the importance of establishing public records protections for public agencies and private companies; (3) the importance of promoting cybersecurity; and (4) the importance of defining ethical regulations for making decisions based on data.

- Municipalities considering their own smart city policies or interventions should clearly identify the problem(s) that they want to solve and employ an iterative policy framework that includes: (1) identifying the data relevant to the problem; (2) developing an analytical model; (3) seeking feedback on the model internally and from the public; and (4) using the analytic model to interpret the data gathered from policy and/or implementation and develop the next iteration of the policy and/or intervention.

VI. A FRAMEWORK FOR SMART CITIES

Smart city concepts and innovations are reshaping cities and providing opportunities to support innovation, government efficiency, and environmental sustainability. A smart city is an ecosystem of domains, pilots, innovations, and stakeholders working together at different city scales (from neighborhoods to regional levels) to more efficiently use resources, often with the goals of achieving energy efficiency and taxpayer savings, improving service delivery and quality of life, and reducing adverse environmental impacts.

This study seeks to understand why smart city initiatives are gaining popularity, how they are evolving, and how to replicate their successes and mitigate potential risks. As a starting point, this chapter discusses high-level findings from the authors' research on smart city initiatives. Next, it presents a three-phase framework for: (1) understanding the problems that smart city initiatives are trying to solve and what strategies might be beneficial; (2) creating institutional capabilities to foster inter- and intra-agency collaboration and an environment for experimentation; and (3) implementing and evaluating pilots and strategies that focus on quality-of-life outcomes at three scales: neighborhood, city, and regional. Finally, this chapter concludes by summarizing some key takeaways.

This framework is based on the authors' experiences with the US DOT Smart City Challenge (2016), the Smart Cities Lab (Lab), and the Texas Innovation Alliance (Alliance). Starting in 2018, the Lab and Alliance engaged the Lab's initial nine cities with the 12 Texas cities to develop a collaborative research plan, called the "Smart City Initiative." This plan focused on working with the 21 cities to (1) determine the best methods for providing technical assistance to the cities, and (2) gain understanding on how the cities approached issues related to mobility and social equity (e.g., mobility strategies for underserved communities, such as shared micromobility).

The Smart City Challenge was a USDOT initiative to stimulate partnerships among the public sector, major institutions, and private sector in the form of committed funds, in-kind contributions, and administrative streamlining to demonstrate the potential of integrated data, ITS, and applications to improve safety, enhance mobility, and address climate change.

Smart Cities Lab is a peer-to-peer network, stitching together investments in innovative mobility across multiple cities into a single platform to work collectively to solve common challenges.

The Texas Innovation Alliance is an action network of local, regional, and state agencies and research institutions who are committed to addressing community mobility challenges by creating a platform for innovation to leverage collective expertise, resources, and best practices.

PLANNING FOR SMART CITY INITIATIVES

The 21 cities comprising the Smart City Initiative are employing technology and innovative planning/testing frameworks in seven core areas: (1) smart energy and environment; (2) smart transportation; (3) smart governance; (4) smart workforce; (5) smart living; (6) smart economy; and (7) smart connections. Each of these are described in greater detail in Figure 3.

A smart city works across jurisdictions, agencies, and economic sectors to build regional innovation that ultimately produces a "smart city." Simply stated, smart city attainment is the sum of regional innovators, and every stakeholder plays a critical role. Innovation is not outsourced. A smart city represents a region of collaborators and innovators.

Smart Energy & Environment

- Transitioning to renewable and zero carbon energy sources
- Protecting environment, while promoting economic innovation
- Protecting environment through open space, active and passive recreation, air and water quality protection, and redeveloping brownfield sites

Smart Transportation

- Ensuring equitable, on-demand, multi-modal transportation access
- Minimizing congestion and maximizing infrastructure and operational efficiency

Smart Governance

- Fostering a culture of innovation and forward thinking action
- Leveraging big data and artificial intelligence to improve service delivery, operational efficiency, and social equity

Smart Workforce

- Developing a workforce that can adapt to a changing economy
- Embracing creativity and innovation in the workforce

Smart Living

- Providing opportunities for a healthy lifestyle including: active transportation, healthcare, and healthy food
- Planning for affordable housing and aging in place
- Programming for arts, culture, and education

Smart Economy

- Promoting innovation and entrepreneurship
- Promoting an environment where businesses are productive, efficient, and competitive

Smart Connections

- Connecting people, stakeholders, institutions, and technology
- Enabling high-speed and affordable connectivity through online access (e.g., Wi-Fi), mobile broadband, cellular/5G, and other sources
- Adapting for changing technological innovations

Figure 3. Seven Smart City Domains

This network of 21 cities is working on smart city innovations across multiple domains and fostering high levels of collaboration with other public agencies, the private sector, and non-governmental organizations (NGOs). This collaboration encompasses a "pyramid of innovation," which starts with the individual innovator and becomes progressively more advanced, culminating in increased regional innovation and multi-stakeholder collaboration (see Figure 4 below).

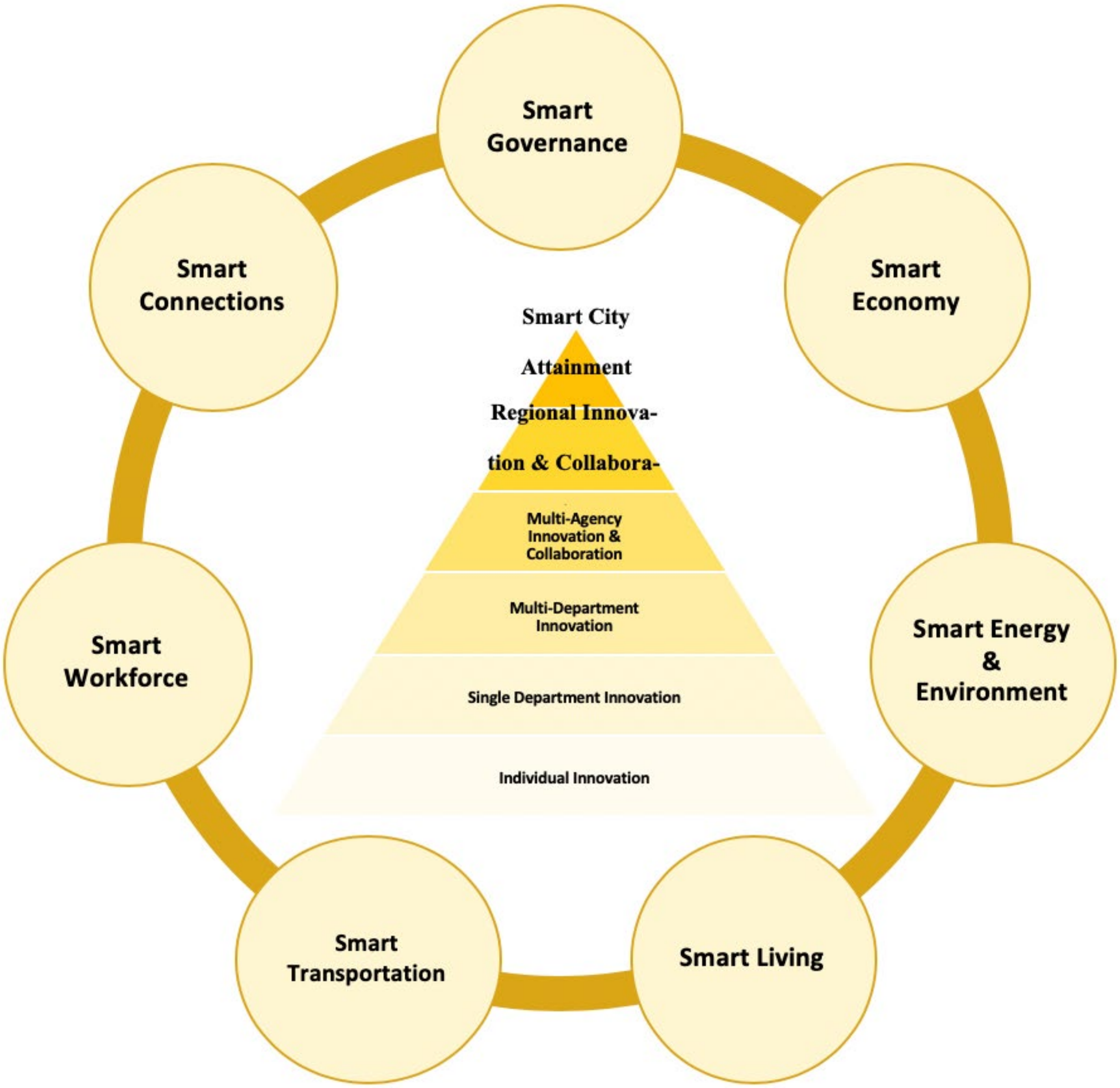

Figure 4. Smart City Domains and Pyramid of Innovation

SMART CITY PLANNING, PILOT IMPLEMENTATION, AND EVALUATION FRAMEWORK

Based on lessons learned from the US DOT Smart City Challenge and the Smart City Initiative, the authors of this report developed a smart city framework, which can be replicated across the globe. This framework entails a three-phase planning, pilot implementation, and evaluation process that involves problem understanding, collaboration, and experimentation in order to yield potential solutions (Figure 5). This framework builds upon the "design thinking" and "communities of practice" methodologies (described below).

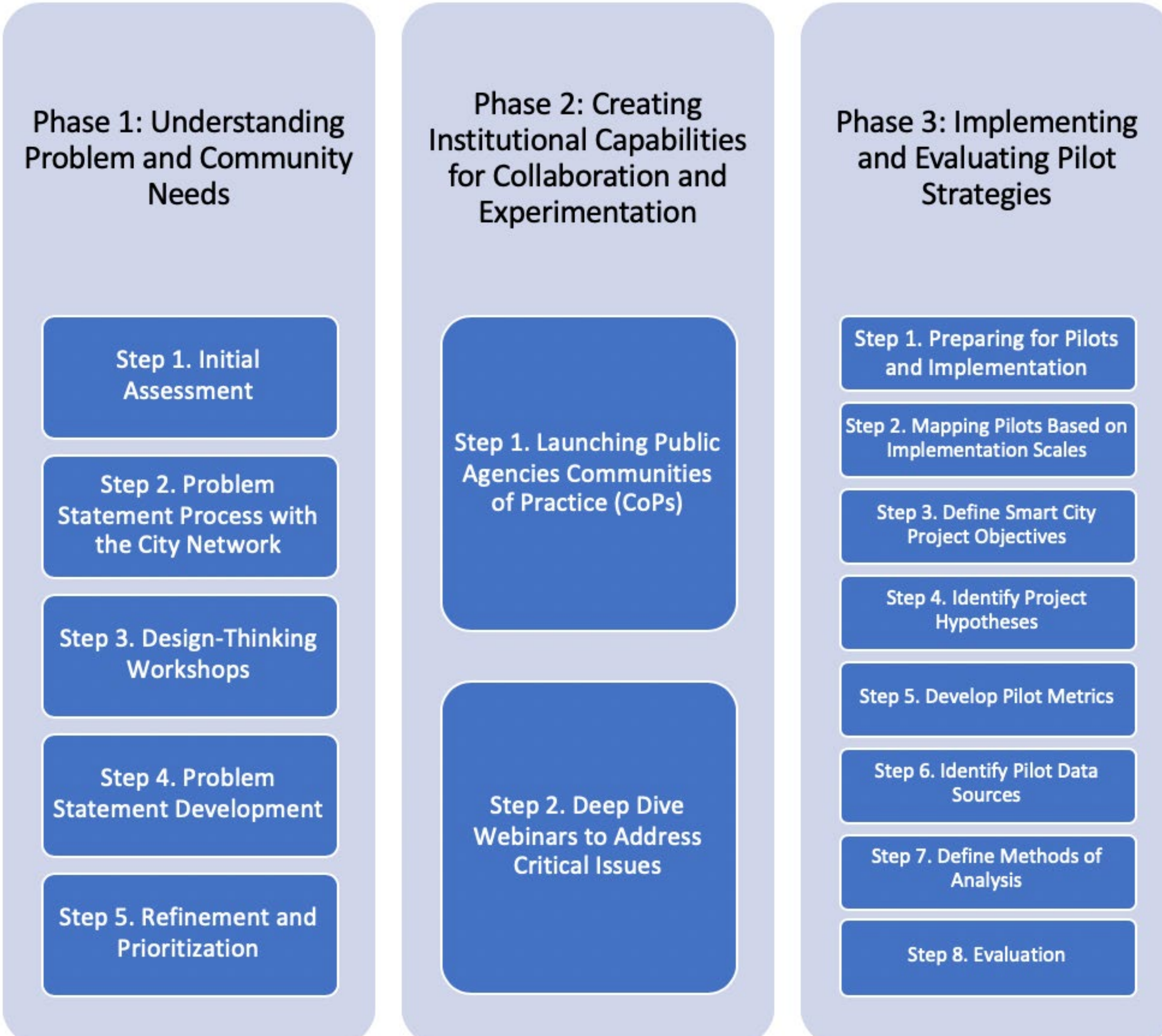

Figure 5. Three-Phase Smart City Planning, Implementation, and Evaluation Framework

Phase 1 is comprised of an initial assessment, design-thinking workshops, and problem statement development, undertaken to understand community concerns. This is followed by Phase 2, which includes a refinement and prioritization process and communities of practice (CoP) to create institutional capabilities for collaboration and pilot experimentation. Phase 3 is focused on implementing pilot strategies and on evaluation. To create this framework, the authors needed to develop mechanisms (e.g., workshops and problem statement development) to enable the cities to identify their challenges and understand how they relate to other cities to facilitate learning and change. While this represents a unifying framework, each city views itself as distinct, having a unique civic, political, geographical, and cultural identity.

Phase 1: Understanding Problem and Community Needs

This phase defines the problem(s) and identifies the needs of the broader community.

Figure 6. Phase 1 Key Steps

Step 1: Initial Assessment. The first phase begins with an assessment based on numerous in-person interviews with city staff and stakeholders in order to establish a baseline for collaboration and problem identification. As part of this research, the Lab conducted an intensive stakeholder engagement process with over 230 interviews, representing 58 public agencies across nine U.S. cities in 2017: Austin, Denver, Detroit, Kansas City, Omaha, Pittsburgh, Portland, San Francisco, and South Bend. It is important to note that the city network expanded to 21 cities in 2018 - 2019. The initial interviews provide a deeper understanding of each city, characterizes common “global” characteristics and themes across the cities, and identifies possible strategies for each city to develop and implement.

Step 2: Problem Statement Process. The 2016 USDOT Smart City Challenge was built on the idea that if cities understood and defined their mobility challenges, they could better develop strategies that employ technology, data, and innovation. This philosophy has been carried forward through the work of the Lab and the Alliance. The Lab and the Alliance worked to motivate a large network of cities (21, at present) to focus on their challenges and problems rather than rushing to an implementation practice. There are three premises that underpin the formulation of the problem statement development phase:

i. Cities and communities need a process to identify and better understand how their mobility challenges align with and relate to other cities;

ii. Cities and communities who go through the problem statement process using design-thinking principles to break down complex problems into simpler components, empathize with the end user, and better identify with other cities' challenges. Design thinking is a collaborative methodology developed by cognitive scientist and Nobel Prize laureate Herbert Simon in the 1960s to combine human, technological, and strategic principles of problem solving.[1] It is particularly well suited to solving "wicked" or complex problems. Figure 7 shows the principles and steps of the design-thinking process. There are six key steps to the process including: (1) empathize; (2) define; (3) ideate; (4) prototype; (5) test; and (6) implement; and

iii. Operational efficiencies can be gained through better alignment of a city's limited resources with priority problems.

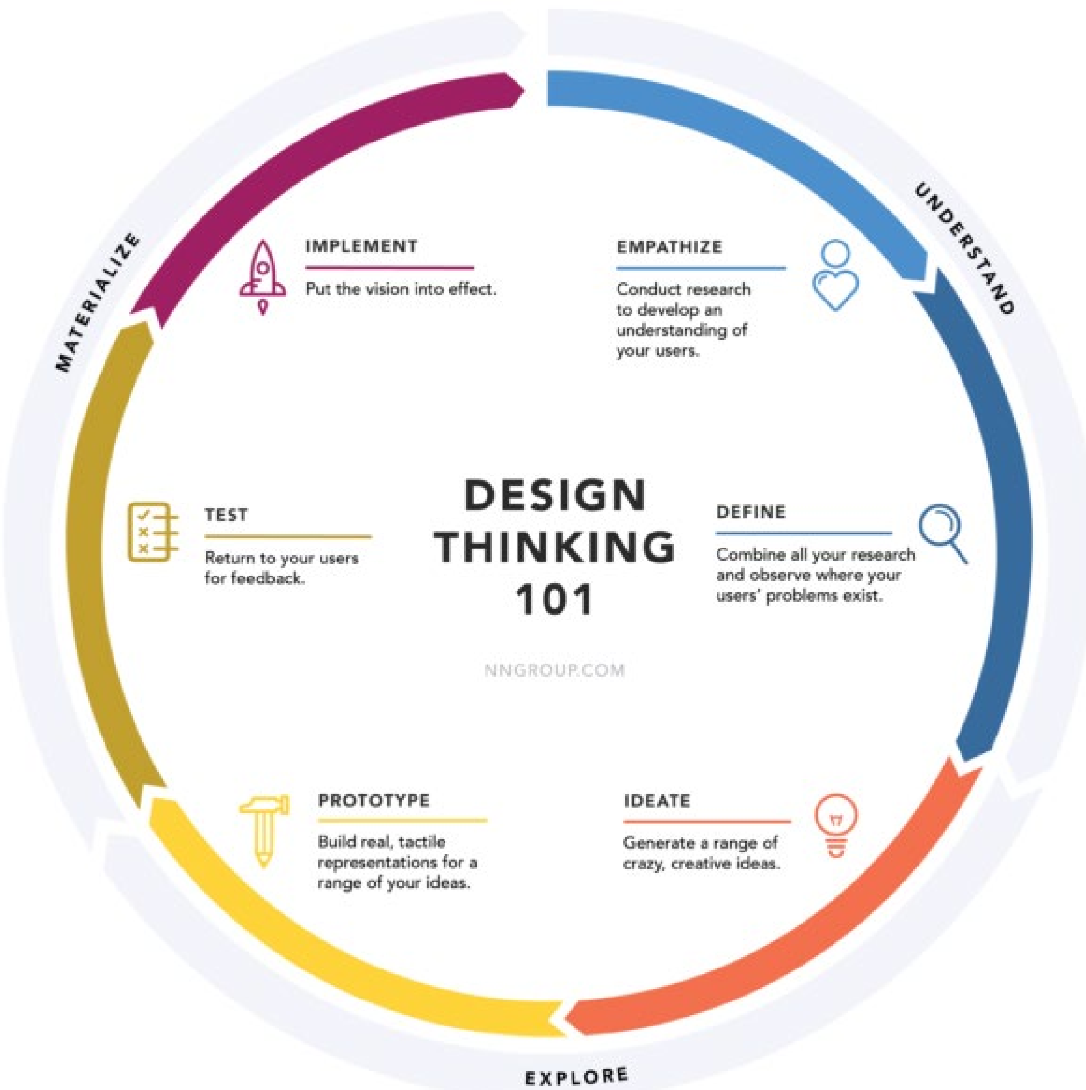

Figure 7. The Design-Thinking Process

Source: NNGroup

Step 3: Design-Thinking Workshops. In 2018, the Lab and the Alliance guided the cities through an intensive problem statement process. To help the cities develop their problem statements, the Lab and the Alliance held three design-thinking workshops in Austin (February 2018), Kansas City (March 2018), and Portland (June 2018). The workshops provided expert guidance and technical assistance to the cities on how to use design thinking to: (1) find the core problem that the city is trying to solve; (2) craft a persuasive problem statement; and (3) pitch a problem statement to the innovation community (citizens, public sector, and private sector) that would result in developing meaningful partnerships and securing resources. The well-attended workshops were facilitated by the Lab and the Alliance, outside professionals from the civic tech community, the startup community, the innovation community, and several other organizations (Electrification Coalition, WSP, Northeast Big Data Hub, Civic Ninjas, GM/Maven, KC Digital Drive, and ICCT) that offered their time to the cities.

Step 4: Problem Statement Development. Each city developed a minimum of five problem statements. The cities had the discretion to choose how to allocate the problem statements across five domains (Seamless Mobility, Real-Time Data, Energy & Sustainability, Equity & Access, and Freight & Logistics). These five areas were defined based on distilling the myriad of mobility and equity issues of interest to the cities. Similar themes were emphasized as part of the 2016 US DOT Smart City Challenge. Ultimately, the Lab/Alliance network cities submitted over 100 problem statements across the five domains. Some cities overachieved (e.g., Austin submitted 14 problem statements), and other cities focused on a single domain (all five of San Francisco's problem statements were focused on Energy & Sustainability).

Step 5: Refinement and Prioritization. The Lab and the Alliance then assisted the cities in re-writing problem statements to make them more impactful and identifying the core problems associated with each one. The process of identifying the core problems was intended to push the cities to identify commonality and begin developing consensus around a smaller set of challenges. It was critical to not lead the cities in finding commonalities but to employ the design-thinking process to enable the cities to organically get to the realizations on their own. The cities finished the problem statement exercise by using a rating process to rate and select the top five problem statements in each of the five domains.

As part of this step, cities are coached on how to clearly communicate their problem statement(s) to a third party and relate their core problems to other cities' core problems. The expert interview process that began each city's engagement and the problem statement processes informed the parameters for the next phase of the research by employing the top problem statements to define the Communities of Practice (CoP) and the topics for deep dives (or learning exchanges across the cities). CoPs are agency-only engagements that promote collaboration across the smart cities network.

Phase 2: Creating Institutional Capabilities for Collaboration and Experimentation

Phase 2 sets the stage for multi-stakeholder collaboration to support strategic experimentation to solve key city problems.

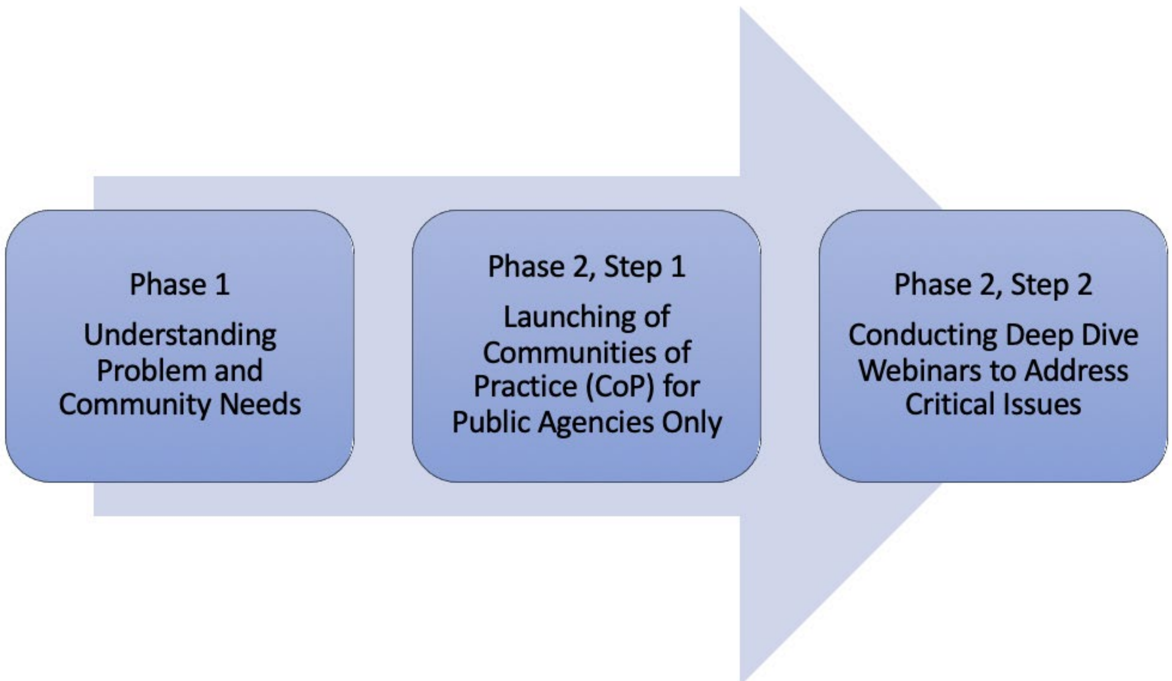

Figure 8. Phase 2 Key Steps

Step 1: Launching of Communities of Practice (CoP) for Public Agencies Only. The concept of "Communities of practice" (CoP), where a group of people share a craft or profession, was first proposed by cognitive anthropologist Jean Lave and educational theorist Etienne Wenger in 1991, who theorized that communities can evolve naturally around information sharing, as well as storytelling, because of common interest in a particular area, or around deliberately creating with the goal of gaining knowledge on a topic.[2] The Lab's detailed assessment in each of the initial nine cities in 2017 enabled a better understanding of the cities' priorities and their ways of addressing these priorities. The Lab's network of cities shared that they felt they were over-convened at conferences and meetings and overwhelmed by the invasion of vendors selling technology products. The public agencies wanted an agency-only peer-to-peer network that would allow them to learn what works, and more importantly what does not work, from each other. Interestingly, the Alliance conducted a strategic planning process that yielded similar results on the need to establish a peer-to-peer network.

Five CoPs were established, corresponding to the problem statement domains: (1) seamless mobility; (2) real-time data; (3) energy and sustainability; (4) equity and access; and (5) freight and logistics. As part of the five CoPs, the Lab and the Alliance: (1) sought input from the participating cities on content and programming; (2) established the effort as a city-led process (as opposed to a NGO-led process); (3) identified public agency co-chairs for each of the five CoPs; (4) built a governance structure for the multi-city network; and (5) established a steering committee to oversee all five CoPs. The cities wanted the five CoPs to be restricted to public agencies, in order to help in building a trusted space for sharing successes and failures.

Each CoP typically meets once a month to discuss and share information including:

strategies and tactics for addressing the problem statements; what works and what needs improvement; best practices; emerging issues and technologies; and updates on various initiatives. Since the April 2018 launch, the CoPs have yielded enthusiastic participation and a potent low-cost platform to share knowledge in real time and develop trust relationships among the cities. As of Spring 2019, the Lab and Alliance had over 250 people participating from 67 public agencies in 21 cities.

Step 2: Deep Dive Webinars to Address Critical Issues Facing Cities. The Lab and the Alliance used the problem statement process to identify content to use in the CoPs' webinars, to educate the cities on challenges and strategies. The Lab and Alliance bring all five CoPs together for important cross-cutting topics including: (1) open payment platforms; (2) shared micromobility; (3) the use of data repositories (centralized clearinghouses for data from IoT devices, social media services, mobile apps, and operations software); and (4) access to non-emergency medical care. The deep dives consist of:

- Identifying timely topics (e.g., scooter injuries, automated vehicles for the disabled and aging communities, charging infrastructure for electric vehicles, managing the rights-of-way, data sharing agreements, access to jobs in low-density areas, etc.);
- Drafting a deep dive introduction to each topic;
- Curating deep dive topics by recruiting three to four public agency experts (often drawn from the 65 participating public agencies), and experts from NGOs, universities, and state and federal governments;
- Moderating an hour-long webinar where each expert presents for approximately ten minutes;
- Facilitating questions and answers at the end of the webinar; and
- Distributing the recorded webinar, presentations, and other materials to the participants of the CoPs.

The Lab and the Alliance conducted over 30 deep dives between April 2018 to May 2019. A list of these deep dives is included in the Appendix A.

Phase 3: Implementing and Evaluating Pilot Strategies

This phase involves preparing for pilot implementation and evaluation. See Figure 9 below for an illustration of the eight key steps.

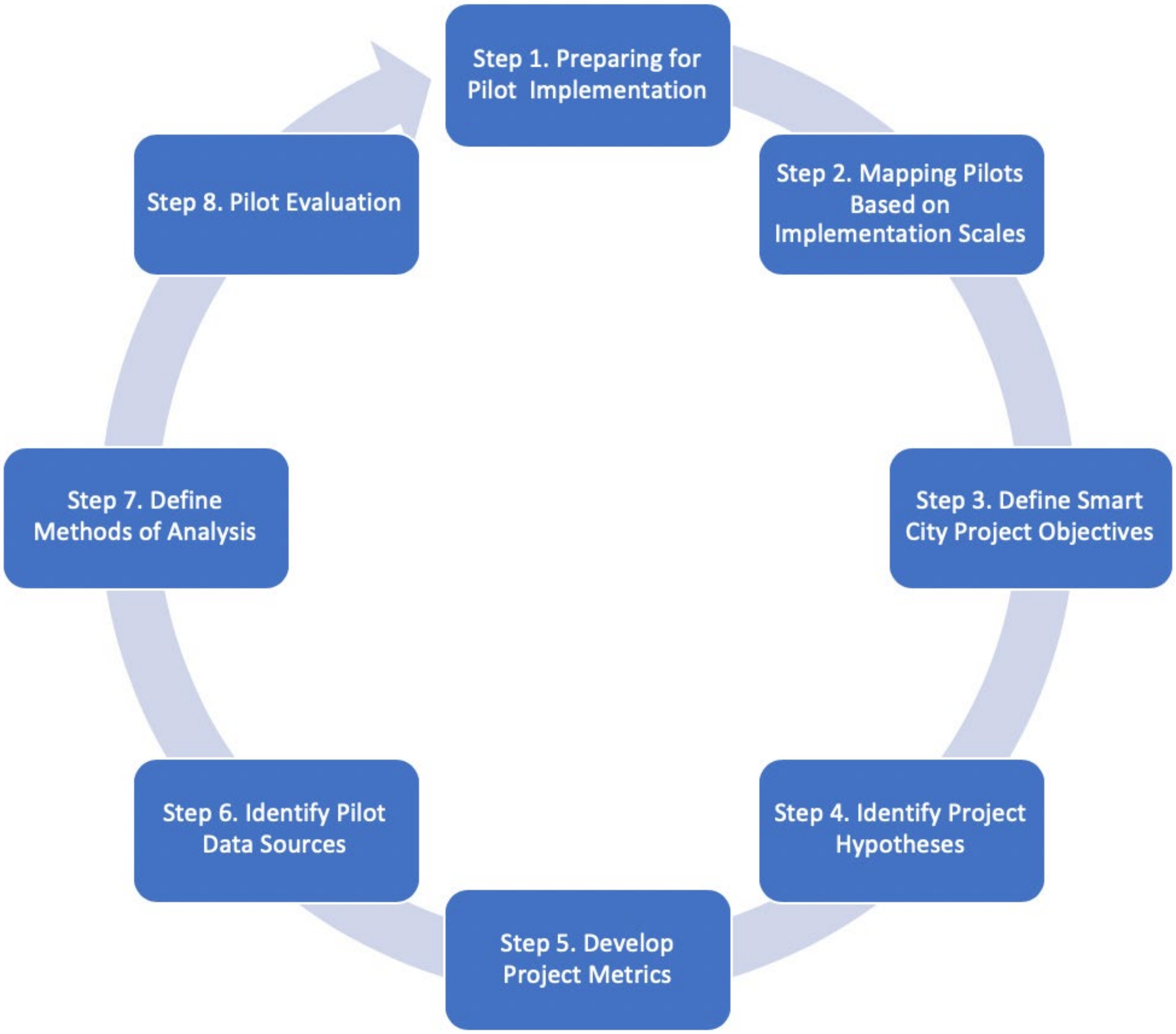

Figure 9. Phase 3 Key Steps

Step 1. Preparing for Pilot Projects and Implementation

Pilot testing is a key tool that can help communities experiment with smart city innovations in order to test how existing policies, projects, and processes can be performed using a new approach. Pilot projects can play a key role in helping the public sector prepare and implement smart city innovations, validate technical and institutional feasibility of smart city innovations, measure the impacts of specific programmatic deployments, and serve as venues for evaluating public policies and regulations that could either support or hinder smart city innovations. Pilots also enable communities to try new smart city innovations, monitor success, adapt if necessary, and reduce the risk of failures and maximize the potential for success.

Step 2. Mapping Pilots Based on Implementation Scales

Smart city pilot projects can be organized by their scale of focus: neighborhood, city, or region (see Table 1). This categorization can aid in organizing and understanding project dynamics and impacts at the appropriate scale using a quantitative approach.

Neighborhood-scale projects aim to deploy smaller pilot projects specific to neighborhood needs and context; city projects encompass intracity travel; and regional pilots cover the entire regions and interregional travel. Naturally, the regional approach requires larger-scale surveys and impact analysis. Pilot projects can provide laboratories for testing and implementing large-scale change, and creating a model that other cities can replicate and customize. As part of the smart city initiative and pilot planning process, it is important for smart city stakeholders to understand the type of scale at which they are targeting smart city strategies.

Table 1. Smart City Pilot Scales

Scale	Defining Characteristics
Neighborhood	Neighborhood smart city initiatives to deploy smaller pilot projects specific to neighborhood needs and context. Neighborhood initiatives can also include university campuses, office parks, airports, planned unit developments, apartment complexes, and business improvement districts. Examples of neighborhood pilots include the development of individual mobility hubs and neighborhood EV charging infrastructure.
City	City or local smart city initiatives are generally undertaken by local governments, often simply to respond to citywide needs. Examples of city-level pilots include connected wireless technologies for automated vehicles and automated public transportation, city-wide equity initiatives, etc.
Regional	Generally undertaken by regional entities and involve a macro-level approach to implementation (i.e., larger scale pilots covering regional geography, larger samples, and a regional study population). Examples of regional pilots include integrated payment and mobility applications, regional pricing initiatives, and smart transportation corridors.

As part of pilot planning and deployment, it is important for communities to evaluate smart city pilot implementation to understand what works and what does not work. When evaluating a smart city project, establishing an evaluation framework can help to define project objectives, identifying project hypotheses, developing performance metrics, identifying sources of data, and defining methods of analysis.

Step 3. Define Smart City Pilot Objectives

In this step, the public agency defines the goals of the smart city pilots project. For example, pilot goals could include “reducing average travel times by 10-minutes,” or “reducing GHG emissions by 30% within seven-years.”

Step 4. Identify Pilot Hypotheses

The next step is for the public agency to develop hypotheses that can be tested as part of the evaluation (e.g., “the average travel time of the population using bus route 30 will fall when using this bus route”).

Step 5. Develop Pilot Metrics

After the objectives and hypotheses have been defined, performance metrics or what is being measured to determine if project objectives have been met should be defined. Performance metrics can be used by a variety of local and regional stakeholders. For example, public agencies may use performance metrics to develop smart city policies and programs or to aid in their understanding of their existing state of the city (or state of the region). Municipal and regional service providers can use performance metrics to help implement smart city initiatives. Residents and non-profits can employ performance indicators to understand the impact of smart city initiatives on quality of life. Finally, academia can use performance indicators to quantify and measure the impact and effectiveness of smart city initiatives. Additionally, performance metrics allow different cities to compare smart city project and program effectiveness when comparable performance metrics are employed. Developing project metrics can also be useful because it can help identify desired data sources and gaps. Due to the multi-disciplinary nature of smart cities, it is not possible to identify all metrics across all smart city disciplines that could be required for performance monitoring. Examples of some smart city performance metrics that could be used for transportation pilots and implementation are included in Table 2. Performance metrics should be comparable with other smart city disciplines (i.e., transportation, energy, etc.) where applicable for effective multi-disciplinary comparisons across smart city projects.

Table 2. Sample Smart City Transportation Performance Metrics

Category	Hypothesis/Research Question	Sample Performance Metrics
Safety		*Crashes…*
	Have vehicle crashes declined?	per million VMT
	Have bicycle crashes declined?	per 1,000 cyclists
	Have pedestrian crashes declined?	per 1,000 pedestrians
		Injuries/fatalities…
	Have vehicle injuries and fatalities declined?	per million VMT
	Have bicycle injuries and fatalities declined?	per 100,000 cyclists
	Have pedestrian injuries and fatalities declined?	per 100,000 pedestrians
Congestion	Is congestion getting worse?	Roadway/Intersection Level of Service (LOS) Travel time to work (minutes) Average vehicle occupancy
	Are fewer people driving to work alone?	
Roadway Demand	Are more workers telecommuting?	VMT per employee
		Average…
	Are people driving less?	Number of telecommute days per worker; per month Daily VMT per capita Daily number of trips

Category	Hypothesis/Research Question	Sample Performance Metrics
Public Transit Ridership	Is public transit ridership increasing?	Modal split by location and time of day
	Is public transit service available for travelers at all hours?	Ratio of average public transportation journey time at 8am to noon on the average weekday Ratio of average public transportation journey time at noon on the average weekend day to the journey time at noon on the average weekday
Public Transit Accessibility	Are people able to reach destinations using public transportation?	Number of jobs/residents/trip origins/trip destinations within ¼-mile radius of a public transit stop Number of households within a 30-minute public transit ride of major employment centers Percentage of workforce that can reach their workplace by public transit within one hour with no more than one transfer
Energy Efficiency	Is society achieving optimal energy efficiency in the transportation system?	Total transportation carbon dioxide (CO2) emissions per capita Total transportation CO2 emissions per household Passenger transportation CO2 emissions per capita
Land Use	Are households living in locations with mixed land uses?	Ratio of jobs to housing (employment-to-dwelling unit ratio)
	Is raw land being consumed by new transportation infrastructure and/or new development served by new transportation infrastructure?	Acres of undeveloped land or farmland converted to development
Affordability	Is transportation affordable?	Percent of annual household income spent on transportation Average cost per mile Average cost per trip
Equity	Is the transportation network equitable?	Average trip time for people with disabilities compared to the entire population for like trips Average trip time for older adults compared to the entire population for like trips Average wait time for pickup for people with disabilities compared to the entire population for like trips

Source: Adapted from Shaheen et al. 2017. For additional metrics, please refer to “Understanding How cities can link smart mobility priorities through data” available at: https://escholarship.org/uc/item/7303t6sw.

Step 6. Identify Pilot Data Sources

In the next step, public agencies will define data sources needed to evaluate project performance metrics and work with project partners to develop data sharing and data use agreements early in the pilot or implementation process.

Step 7. Define Methods of Analysis

In this step, the public agency will define the methodologies that will guide data analysis. Advanced models or statistical analyses are not always required to answer important questions. Certain metrics can be evaluated by simply aggregating or plotting data to find averages or basic trends.

Step 8. Pilot Evaluation

The next step is for a public agency to implement the evaluation.

A SMART CITY TYPOLOGY

A review of the Smart City Initiative network of 21 cities revealed an emerging typology of smart cities. Smart cities occur in a variety of settings – urban, suburban, rural, and even regional. Smart city innovations are occurring in mature cities, often involving issues of infill development, congestion management, equity, and efforts to revive blighted urban centers. Smart city innovations are also occurring in fast growing suburban areas developing for the first time, attempting to address issues of new infrastructure, site planning, and open space preservation. Smart city innovations are also occurring in small towns and rural areas that includes improving access to critical services, such as healthcare and jobs, and economic development. Finally, smart city innovations are also occurring at the regional level to maintain a jobs-housing balance, address issues of affordable housing and transportation, and enhancing economic competitiveness with other regions. Smart cities can include all of these different communities and spatial scales.

Building off of the work developed by Chin[3], this study's authors conducted expert interviews that identified an emerging smart city typology. This typology is influenced by population growth, regional economies, and cost of living and affordability issues. This typology, described in Figure 10, includes four types of smart cities and regions: 1) tech-oriented cities and regions; 2) economic revival cities and regions; 3) growth cities and regions; and 4) small and rural communities.

Figure 10. Typology of Four Emerging Smart Cities / Regions

SUMMARY

Smart cities can be described as stakeholder innovation and collaboration across seven smart city domains:

- The Seven Smart City Domains include: 1) smart energy and environment; 2) smart transportation; 3) smart governance; 4) smart people; 5) smart living; 6) smart economy; and 7) smart connections.

- A smart city represents a region of collaborators and innovators working to advance all seven domains. This collaboration and innovation can be described as a pyramid of innovation that starts with the individual innovator and becomes progressively more advanced, culminating in increased regional innovation and multi-stakeholder collaboration.

As part of this research, the authors have developed a three-phase smart city planning, implementation, and evaluation framework to aid cities engaging in smart city development. This process entails understanding the cities' problems, collaboration across governance and stakeholder groups, and pilot experiment to identify potential solutions. Phase 1 includes an initial assessment, design-thinking workshops, and problem statement development to understand community concerns. This is followed by Phase 2, which includes the problem statement refinement and prioritization process and communities of practice to create institutional capabilities for collaboration and pilot experimentation. Phase 3 is focused on pilot strategy implementation and evaluation.

Implementing and evaluating smart city pilots is important for communities in understanding what works and what does not work. In evaluating smart city projects:

- Public agencies can use an eight-step process to implement and evaluate smart city pilots; this includes establishing an evaluation framework that defines project objectives, identifies pilot hypotheses, develops performance metrics, identifies sources of data, and defines methods of analysis.

Building on Chin's work and the 21 smart city network, the authors advanced a smart city typology, which could be helpful in classifying a range of approaches across US cities. This typology can help to guide the public and private sectors and communities interested in navigating the smart city landscape. Ultimately, this typology could be used for categorizing the range of problems and strategies by city type to further facilitate collaboration and knowledge transfer. The four smart city typologies include:

- Tech-oriented communities and regions driven by technological innovation, often trying to address related challenges, such as housing affordability and cost of living issues;

- Economic revival cities and regions reinventing their economies for post-industrial economic development;

- Growth cities and regions that are growing economically and spatially, typically with fewer challenges associated with housing affordability and cost of living; and

- Small and rural communities investing in placemaking and workforce development to retain talent.

VII. SHARED MICROMOBILITY

In recent years, shared micromobility growth in U.S. cities has been on a steep growth curve from the early 2010s through 2018. Shared micromobility systems offer shared active transportation and low-speed modes for first-and-last mile trips, many-mile trips, or both in an urban environment.[4] Shared micromobility – the shared use of a bicycle, scooter, or other low-speed mode – is an innovative transportation strategy that enables users to have short-term access to a transportation mode on an as-needed basis. Shared micromobility includes various service models and transportation modes that meet the diverse needs of travelers, such as station-based bikesharing (a bicycle picked-up from and returned to any station, dock, or kiosk) and dockless bikesharing and scooter sharing (a bicycle or scooter picked up and returned to any location). Thus, shared micromobility can facilitate connections to and from public transit and provide a means to make local trips within a service area. In this chapter, the authors provide a case study of shared micromobility (e.g., dockless scooters and bikesharing). The authors highlight this area because the Smart Cities Network indicated this was one of the most pressing issues they faced in 2018. In this chapter, the authors provide: 1) micromobility taxonomy/definitions, 2) a brief background on developments, 3) benchmarking data from the P2P city network, 4) a micromobility policy overview from the P2P city network, 5) a summary of micromobility challenges, and 6) best practices and recommendations.

MICROMOBILITY TAXONOMY AND DEFINITIONS

Shared micromobility includes a number of service models and travel modes to meet the diverse needs of users:

Service Models

Business-to-Consumer (B2C) Services provide individual consumers with access to business owned and operated micromobility services, such as a fleet of bicycles or scooters. These services are typically provided through memberships, subscriptions, short-term passes, user fees, or a combination of pricing models.[5]

Peer-to-Peer (P2P) Services involve the sharing of privately owned micromoblity equipment where companies broker transactions among micromobility owners and guests by providing the organizational resources needed to make the exchange possible (e.g., locking mechanism, online platform, etc.).[6]

Travel Modes

Bikesharing provides users with on-demand access to bicycles at a variety of pick-up and drop-off locations for one-way (point-to-point) or roundtrip travel.[7] Bikesharing fleets are commonly deployed in a network within a metropolitan region, city, neighborhood, employment center, and/or university campus in one of three service models:

- *Station-based Bikesharing Systems*: In a station-based bikesharing systems, users access bicycles via unattended stations offering one-way station-based service (i.e., bicycles can be returned to any station). See Figure 11 (below), upper left.

- *Dockless Bikesharing Systems*: In a dockless bikesharing system, users may check out a bicycle and return it to any location within a predefined geographic region. Dockless bikesharing can include business-to-consumer operator or peer-to-peer systems enabled through third-party hardware and applications. See Figure 11, upper right.

- *Hybrid Bikesharing Systems*: In a hybrid bikesharing system, users can check out a bicycle from a station and end their trip either returning it to a station or a non-station location or users can pick up any dockless bicycle and either return it to a station or any non-station location.

Scooter sharing allows individuals access to scooters by joining an organization that maintains a fleet of scooters at various locations. Scooter sharing models can include a variety of motorized and non-motorized scooter types. The scooter service provider typically provides gasoline or electric charge (in the case of motorized scooters), maintenance, and may include parking as part of the service.[8]

- Standing Electric Scooter Sharing: A shared electric-powered scooter with a handlebar, deck and wheels that is propelled by an electric motor. The most common scooters today are made of aluminum, titanium and steel. See Figure 11, lower left.

- Moped-style Scooter Sharing: A seated-design shared scooter (electric or gas-powered) generally having a less stringent licensing requirement than motorcycles designed to travel on public roads at slightly higher speeds than bicycles. See Figure 11, lower right.

Figure 11. Common Types of Shared Micromobility Services
Image reprinted from: Shaheen & Cohen, 2019.

While the impacts of dockless models of shared micromobility (e.g., dockless bikesharing and scooter sharing) have not been extensively studied, anecdotal evidence suggests that micromobility may be an effective transportation option to reduce auto ownership, vehicle miles traveled (VMT), and vehicle emissions; potentially increasing public transit use; and allowing more efficient use of the public rights-of-way (e.g., infrastructure can accommodate more travelers in less space). As such, the dramatic growth of shared micromobility across the U.S. is not only impacting urban transportation but has the potential to support common public agency goals such as: congestion mitigation, air quality, parking management, climate action targets, and multimodal integration.

Although shared micromobility has been in existence for decades, it has recently gained prominence due to the rapid expansion of bikesharing and scooter sharing systems into new locations and the scale of their operations, based in large part to improvements in information technology that enables mobile access and equipment communications, tracking, and geofencing and improvements in batteries and charging enabling the electric bike and scooter growth.

BACKGROUND: SHARED MICROMOBILITY ORIGINS TO THE PRESENT

The recent growth of shared micromobility over the past decade can be summarized in terms of milestone periods (Figure 12):

1. Origins of IT-Based Micromobility and Station-based Bikesharing (2007 to 2012);

2. The Growth of Peer-to-Peer Bikesharing (2012 to 2014);

3. Introduction of Dockless and Geo-Fencing Technologies (2014 to 2016); and

4. Growth of Dockless Bikesharing and Scooter Sharing (2017 to Present).

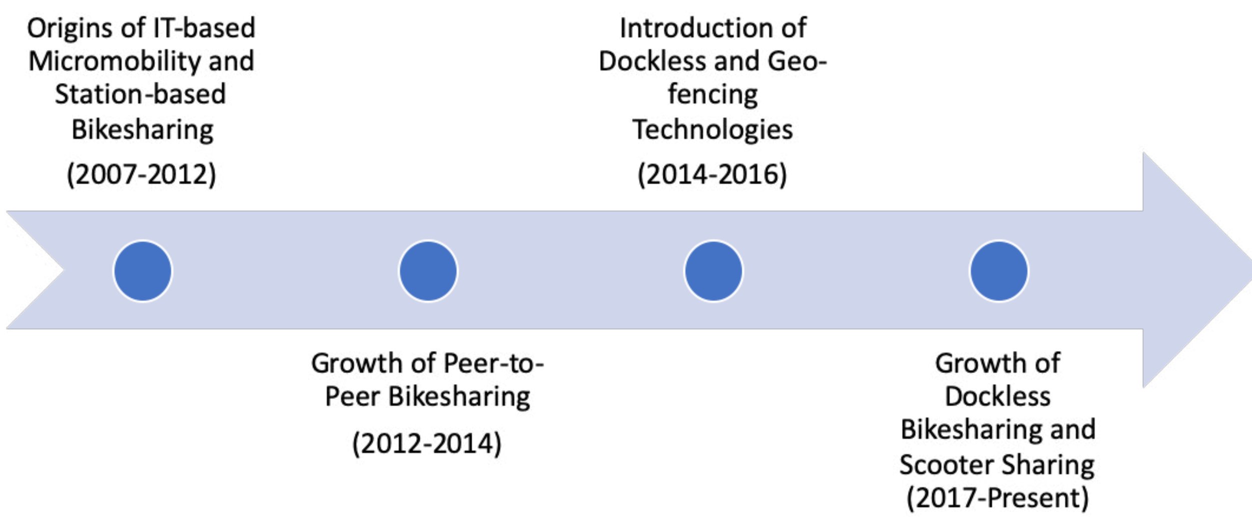

Figure 12. Shared Micromobility Milestones

Origins of IT-Based Micromobility and Station-based Bikesharing (2007 to 2012): North America's first information technology (IT) enabled bikesharing system, Tulsa Townies, started operating in 2007 in Tulsa, Oklahoma. Tulsa Townies was the first solar-powered, fully automated station-based system in the world. It provides service free of charge with a credit card refundable deposit. By 2012, IT-enabled station-based bikesharing had grown to 22 operators in the U.S. claiming approximately 884,442 users sharing 7,549 bicycles.[9]

The Growth of Peer-to-Peer Bikesharing (2012 to 2014): Approximately five years after the launch of station-based bikesharing, a variety of dockless technologies began to emerge enabling new operational and business models. In 2012, Spinlister, a smartphone application, launched a peer-to-peer bicycle rental marketplace where a bike owner could make their bicycle available to others for short time periods, enabling direct exchanges between individuals via the Internet. Spinlister eventually shut down in April 2018, but it relaunched in January 2019 with new features including remote locking and bicycle delivery (a bicycle brought to a user).[10] At the same time that Spinlister was launching, in 2013 another company BitLock created a keyless bike lock accessed via smartphone enabling another peer-to-peer bikesharing option.[11]

Introduction of Dockless and Geo-Fencing Technologies (2014 to 2016): A number of bikesharing startups, including Social Bicycles (known as SoBi and later acquired by Uber as JUMP) launched dockless or flexible docking bikesharing systems featuring “smart bikes” hosting the locking mechanism on the bike rather than the dock. Dockless and flexible docking systems enable users to pick-up and drop-off bicycles anywhere within a geographic area by locking the bicycle to a bikesharing station, existing bicycle parking, street furniture, or a designated bikesharing rack.[12] Users identify bicycle availability and locations in real time through mobile or Internet applications or via bikesharing kiosk screens. The geographic proximity of bikesharing (docked and dockless systems) can be limited through “geo-fencing.” A geo-fence is a virtual perimeter, which limits the range of mobility of an enabled bicycle by comparing the GPS-satellite coordinates of the bicycle to the allowable geographic area.[13]

Growth of Dockless Bikesharing and Scooter Sharing (2017 to Present): Beginning around 2017, the number of bikesharing providers began to grow notably. In addition to docked or station-based services provided by B-Cycle, Motivate, Zagster, and Social Bicycles, a number of new dockless vendors began to enter the marketplace including JUMP (formerly Social Bicycles), Limebike, MoBike, Ofo, and Spin and an array of smaller vendors and service providers.[14] Between 2016 and 2017, the number of bikesharing bikes more than doubled from 42,500 to approximately 100,000. Over this period, station-based bikesharing fleets grew approximately 25% to 54,000 station-based bicycles.[15] NACTO estimates that dockless bikesharing accounted for approximately 44% of the fleets and 4% of the trips, and station-based bikesharing accounted for approximately 56% of the fleets and 96% of the trips in the U.S. as of December 2017. Between 2010 to 2017, 123 million bikesharing trips were completed in the U.S., with 35 million trips completed in 2017 alone.[16] As of May 2018, the U.S. had 261 bikesharing operators (station-based and dockless) with more than 48,000 bicycles (Russell Meddin, unpublished data). In 2018, cities and state regulatory agencies responded to the sudden emergence of dockless standing electric scooters in the public rights-of-way. As of July 2018, e-bikes and standing electric scooters “exist in a regulatory grey area,” with inconsistent regulations between cities and varying specifications for where the devices can operate and how the devices are classified.[17]

BENCHMARKING DATA FROM THE SMART CITIES LAB P2P CITY NETWORK

In 2018, shared micromobility emerged as the primary issue confronting the Smart Cities Lab peer-to-peer (P2P) city network, predominantly driven by the growing number of dockless bikesharing and scooter sharing operators and equipment on local infrastructure. Using an online data scraping technique documenting the size and scale of micromobility from operator websites, news stories, and other sources, the authors obtained estimates of the scale of dockless bikesharing and scooter sharing for the 21 cities across the Smart Cities Lab P2P city network. Cities without services or where data were unavailable are not depicted on the maps. Using these data, the authors estimate that there are 20,502 dockless bikesharing bicycles being shared across eight of the network’s cities (see Figure 13). Ten thousand of these bikes were located in Seattle alone. It is also estimated that there were 26,492 standing electric scooters being shared across ten of the network’s cities as of December 2018 (see Figure 14). Approximately 7,390 of these standing electric scooters were deployed in Austin. Within the network cities, moped-style scooter sharing is currently available in Pittsburgh and San Francisco as of December 2018 (data were only available for Pittsburgh – see Figure 15).

Figure 13. Estimated Scale of Dockless Bikesharing in the Smart Cities Lab Peer-to-Peer City Network (as of December 2018)

Note: Dallas: *In February 2018, Dallas had 18,000 dockless bikes, the largest deployment in the country. In June 2018, all but two operators withdrew their bikesharing fleets from Dallas.*

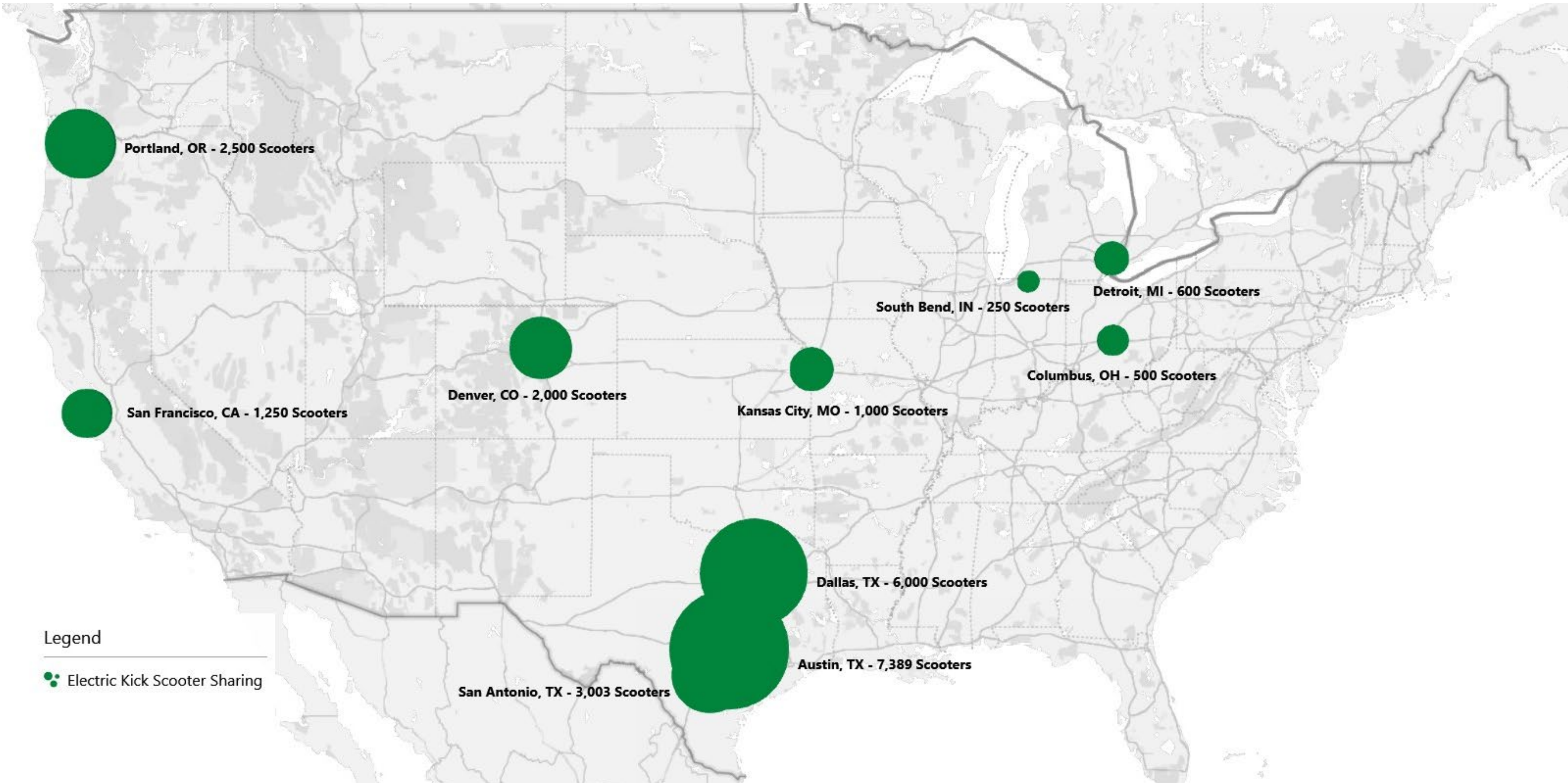

Figure 14. Estimated Scale of Dockless Standing Electric Scooter Sharing in the Smart Cities Lab Peer-to-Peer City Network (as of December 2018)

Note: Columbus: *The number of dockless standing electric scooters deployed reflects the latest data reported in August 2018 (Rouan, 2018).*

Figure 15. Figure 15. Estimated Scale of Dockless Moped-style Scooter Sharing in the Smart Cities Lab Peer-to-Peer City Network (as of December 2018)

MICROMOBILITY POLICY OVERVIEW FOR THE P2P CITY NETWORK

As stakeholders in the Smart Cities Lab P2P city network began to confront the rapid growth of micromobility through the Lab's Mobility Innovation Challenge engagement process, many cities identified common issues including: 1) need for public policy to manage curb space; 2) issues with dockless equipment blocking American Disability Act (ADA) access (e.g., scooters or bicycles blocking wheelchair use of curbs and ramps); and 3) need to integrate micromobility into comprehensive transportation planning (modeling, plans, urban design, trip planning, integrated fare payment, etc.). This discussion provides a high-level overview of the diverse policy responses for cities within the P2P City Network where dockless bikesharing and dockless standing electric scooters have been deployed. It is important to note regulation around dockless micromobility is evolving rapidly as cities learn from pilots and respond to public feedback.

As of December 2018, within the Smart Cities Network (of 21 cities), 20 local jurisdictions had existing or pending dockless bikesharing policies, 17[18] had existing or pending policies applicable to standing electric scooter sharing, and two had policies specific to moped-style scooter sharing (See Table 3). San Francisco was the only city to have a policy for all three modes. Portland stood out as the only city in the network operating a hybrid bikesharing program. Arlington, Corpus Christi, El Paso, Ft. Worth, Houston, and Omaha were in various stages of deliberation on the approval of a dockless device policy encompassing both bikes and standing electric scooters. Seattle and College Station have banned dockless standing electric scooters. Pennsylvania Department of Transportation regulators were still developing a legal framework for standing electric scooters, which the state considers a motor vehicle, preventing Pittsburgh from permitting operators. Bryan, Texas, located adjacent to College Station, had not yet proposed regulation for any mode. Due to a number of similar policy issues pertaining to dockless bikesharing and standing electric scooter sharing, a number of jurisdictions developed uniform or very similar policies applicable to both modes.

Table 3. Overview of Dockless Micromobility Policies in the Smart Cities Lab 21 Peer-to-Peer City Network

	Arlington, TX	Austin, TX	Bryan, TX	College Station, TX	Corpus Christi, TX	Columbus, OH	Dallas, TX	Denver, CO	Detroit, MI	El Paso, TX
Service Availability										
Services Not Available	🛴🚲🛵	🛵	🛴🛵	🛴🛵	🚲🛵	🛵	🛵	🛵	🚲🛵	🛴🚲🛵
Services Available		🚲[multiple] 🛴[multiple]	🚲	🚲[one]	🛴	🚲[one] 🛴[multiple]	🛴[multiple] 🚲[multiple]	🚲[multiple] 🛴[multiple]	🛴[multiple]	
Policies										
Services Banned	🛴🚲*			🛴						🛴🚲*
No Action Taken	🛵	🛵	🛴🚲🛵	🛵	🛵	🛵	🛵	🛵	🚲🛵	🛵
Released an RFP										
Broadened Existing Policy									🛴[multiple]	
Pilot Program / Trial Period				🚲[one]	🚲🛴**		🛴[multiple]	🚲[multiple] 🛴[multiple]		
Post-Pilot/Post-Trial Permitting		🚲[multiple] 🛴[multiple]				🚲[one] 🛴[multiple]	🚲[multiple]			

	Fort Worth, TX	Houston, TX	Kansas City, MO	Omaha, NE	Pittsburgh, PA	Portland, OR	San Antonio, TX	San Francisco, CA	Seattle, WA	South Bend, IN	Washington, D.C.
Service Availability											
Services Not Available	🚲 🛴 🛵	🚲 🛴 🛵	🚲🛵	🚲🛴🛵	🚲🛴	🛵	🚲🛵		🛴🛵	🛵	🛵
Services Available			🛴		🛵[one]	🚲[one] 🛴[multiple]	🛴[multiple]	🚲[multiple] 🛴[multiple] 🛵[one]	🚲[multiple]	🚲[one] 🛴[one]	🚲[one] 🛴[multiple]
Policies											
Services Banned	🚲 🛴*	🚲 🛴*			🛴	🚲[one]****			🛴		
No Action Taken	🛵	🛵	🛵	🛵		🛵	🛵		🛵	🛵	
Released an RFP			🚲🛴	🚲🛴***							
Broadened Existing Policy											
Pilot Program / Trial Period					🚲***	🛴[multiple]	🚲[multiple] 🛴[multiple]	🚲[multiple] 🛴[multiple]		🛴[one]	
Post-Pilot/Post-Trial Permitting					🛵[one]			🛵[one]	🚲[multiple]	🚲[multiple]	🚲[multiple] 🛴[multiple]

Key

🚲 Dockless Bikesharing

🛴 Standing Electric Scooter Sharing

🛵 Moped-style Scooter Sharing

One Operator

Multiple Operators

* Rules/ordinances are pending approval by City Council as of December 2018.

** Pilot program pending approval by City Council as of December 2018.

*** Scheduled for 2019.

**** PBOT exclusively provides their own hybrid bikesharing system. As of December 2018, PBOT has not considered establishing a permitting process for pure dockless bikesharing.

Eleven local jurisdictions were identified with an existing dockless device policy (policy data were unavailable for South Bend, IN). Ten cities with dockless standing electric scooters were analyzed since Seattle had banned the mode. All eleven cities had dockless bikesharing regulations, although several of these cities regulate both bikes and standing electric scooters under a single framework for dockless devices. Of the two cities with policies on moped-style scooters, San Francisco and Pittsburgh, only San Francisco had publicly available policy information.

The authors' policy scan yielded six key components of a local jurisdiction's dockless device regulation (bikesharing and standing electric scooters):

1. An agreement with operators to access the rights-of-way, either through a pilot program or rules of conduct;

2. Control of the presence of dockless devices on city streets through caps on the number of operators, the maximum number of devices in an operator's fleet, and specific permitted service areas where an operator's devices can be deployed;

3. Control of dockless device parking to minimize obstruction in the rights-of-way;

4. Data collection on dockless devices and activities to ensure operator compliance and inform future policy design;

5. Requirement for historically underserved communities to have equitable access to micromobility devices; and

6. Educating riders on state and local riding laws intended to protect rider and pedestrian safety.

Table 4. High-Level Policy Overview for Dockless Standing Electric Scooter Sharing Regulation

	Operator Agreement		Caps and Service Area Limits			Parking		Data	Equity of Access		State and Local Riding Laws	
	Pilot Program	Permit Application	Cap on Number of Operators	Cap on Devices	Permitted Service Areas	Designated Parking Areas	Cap Incentives for Good Fleet Parking	Frequency of Data Sharing	Equitable Device Distribution	Cash Payment Option	Helmet Required	Sidewalk Riding Allowed Outside Downtown
Austin	·	6 months	No Cap	·	·	·	·	·	·	·	—	·
Columbus	-	6 months	8	·			·	·	·	·	Under 18	—
Dallas	-	6 months	No Cap					4 months			Under 18	·
Denver	·	6 months	5 per mode	·		·		·	·	·	—	—
Detroit	-	-	No Cap	·			·	·	·		Under 19	·
Kansas City	-	6 months	No Cap	·			·	·	·	·	—	—
Portland	4 months	·	No Cap	·		·	·	·	·	·	·	—
San Antonio	6 months	6 months	No Cap					6 months			—	·
San Francisco	·	·	No Cap	·	·	·	·	·	·	·	Under 18	—
Washington D.C.	15 months	6 months	No Cap	·		·	·	·	·	·	—	·

Table 5. High Level Policy Overview for Dockless Bikesharing Regulation

	Operator Agreement		Caps and Service Area Limits			Parking		Data	Equity of Access		State and Local Riding Laws	
	Pilot Program	Permit Application	Cap on Number of Operators	Cap on Devices	Permitted Service Areas	Designated Parking Areas	Cap Incentives for Good Fleet Parking	Frequency of Data Sharing	Equitable Device Distribution	Cash Payment Option	Helmet Required	Sidewalk Riding Allowed Outside Downtown
Austin	·	6 months	No Cap	·	·	·	·	·	·	·	Under 18	·
Columbus	6 months	6 months	8	·			·	·	·	·	Under 18	—
Dallas	-	6 months	No Cap					4 months			Under 18	·
Denver	·	6 months	5 per mode	·		·		·	·	·	—	—
Detroit*	-	-	No Cap	·			·	·	·		—	·
Kansas City*	-	6 months	No Cap	·			·	·	·	·	—	—
Portland	N/A	N/A	N/A	N/A	N/A	·	N/A	N/A	**	·	·	—
San Antonio*	6 months	6 months	No Cap					6 months			—	—
San Francisco	18 months	·	No Cap	·	·	·	·	·	·	·	Under 18	—
Seattle	6 months	·	No Cap	·		·	·***	·	·		·	—
Washington D.C.	15 months	6 months	No Cap	·		·	·	·	·	·	—	·

* Although these cities do not yet have a dockless bikesharing presence, their regulatory policies for dockless devices encompass both bikes as well as standing electric scooters.

** As a city-managed hybrid bikesharing program, Biketown's periodic expansions are based in part on the city's equity and diversity goals.

*** Seattle also expands fleet caps for operators who deploy approved devices (called "adaptive cycles") intended for individuals who have difficulty riding a conventional bicycle. Tricycles, hand-pedaled cycles, and recumbent bicycles are all examples of these special devices (Seattle Department of Transportation (SDOT), 2018, p. 3).

These charts represent the status of policies in December 2018. Corpus Christi, Texas approved a six-month dockless scooter pilot in January 2019

Table 6. High-Level Micromobility Policy Summary from Smart Cities Network

Policy Area	Responses from the Smart Cities Network
Operating Agreements	Portland, San Francisco, and Seattle used competitive applications to limit the number of operators who would deploy dockless devices on their city streets. Detroit had the most open dockless devices program, allowing operators to deploy without an application process. The city only required operators to comply with their guidelines for conduct in the rights-of-way, which included providing data to the city and distributing devices to historically underserved areas.
Street and Sidewalk Management	Dallas and San Antonio had no explicit cap on the number of devices. Like the other Texas cities, Austin lacked an explicit cap on the number of operators, but the city's policy was to incrementally limit the number of devices an operator could deploy outside of the downtown area.[a] Only Austin and San Francisco limited where operators can deploy their devices. Austin tied its geographic limit on operators to its incremental licensing system. Other cities allowed operators to declare the city boundary as their operating area. Washington D.C. has a maximum standing electric scooter speed of 10 mph, the lowest of the cities studied.
Parking Controls	Austin, Denver, Portland, San Francisco, and Seattle created designated parking areas for dockless devices. When a trip ends near a designated parking area, dockless devices must be parked there. Washington D.C. requires dockless bikes to be equipped with a lock-to mechanism, a device that registers when a bike is fixed to a separate object. Portland stands out as the only city with a hybrid system, which combines a network of docking stations, designated dockless parking areas, and the ability to park at any public bike rack for a fee. Denver does not offer a cap incentive for fleet parking – its cap incentive is granted based on deployment to "opportunity areas" a designated area with a historically underserved population. Seattle and Washington D.C. used fleet cap incentives to encourage deploying special assistive vehicles, such as hand cycles or tricycles, that help individuals who face difficulties riding conventional bicycles.
Data	All cities have a requirement for data collection. Dallas and San Antonio required periodic reports from operators. The rest of the cities required real-time data to be provided to the public agency overseeing micromobility services for the city.
State and Local Riding Laws	In all cities, operators recommend riders wear helmets for their personal safety. Sidewalk riding is discouraged in favor of riding in bike lanes whenever possible in all cities. Austin, Dallas, Detroit, San Antonio,[a] and Washington D.C. allow riders to legally ride on sidewalks outside downtown areas where there are fewer bike lanes available. Columbus, Kansas City, Portland, and San Francisco forbid riding standing electric scooters on all city sidewalks. Denver allows standing electric scooters on sidewalks under certain conditions.[b]

a San Antonio permits riders to legally ride on sidewalks in downtown, but prohibits riding in many downtown areas including: parks, plazas, and historic districts.

b Denver allows standing electric scooters on sidewalks under two conditions: 1) there must not be a bike lane available and 2) the street speed limit must be greater than 30 mph.

COMMON MICROMOBILITY ISSUES CONFRONTING CITIES

Additionally, without micromobility stations co-located next to mobility hubs or public transportation nodes, additional policies may be needed to encourage multi-modality. Without the ability to physically co-locate dockless equipment (bikes and scooters) with these other transportation services, digital and fare payment integration is critical. Digital integration can include leveraging application programming interfaces (or APIs) to integrate dockless micromobility with public transportation apps and multimodal trip planners. Los Angeles is developing the Mobility Data Specification (MDS) in conjunction with data scientists from other cities to supply operators with a single, open-source API they can use to supply required real-time data about their fleets. San Francisco, Seattle, and Austin are also contributing to the development of the data standard. In October 2018, Detroit announced a partnership with the National Association of City and Transportation Officials (NACTO) and SharedStreets, a nonprofit developer of tools for transport data, to pilot a new standard for real-time dockless mobility data using data from Lime and Bird. At the point of service, fare integration involves the development of a single fare payment method across multiple modes.[19] For example, in Columbus (the 2016 Smart City Challenge grant winner) dockless operators must tie their services into the Smart Columbus common payment system for multi-modal transportation once development is finished.

> Los Angeles has led the development of the Mobility Data Specification (MDS) in conjunction with data scientists from other cities to supply operators with a single, open-source application programming interface (API) they can use to share required real-time data about their services. San Francisco, Seattle, and Austin are also contributing to the development of the data standard. MDS is a data / API standard that allows the city to gather, analyze, and compare real-time and historical data from shared mobility service providers. The specification also serves as a measurement tool that helps enable enforcement of local regulations. MDS also allows service providers and public agencies to communicate with each other about their services because it consists of two APIs: 1) a service provider API and 2) a public agency API. MDS includes data such as: mobility trips (and routes); location and status of equipment (e.g., available, in-use, and out-of-service); and service provider coverage areas.

Dockless Micromobility and Curb Space Management

With the growth of bikesharing fleets, cities are increasingly confronting questions about curb space management, how to prevent dockless micromobility equipment from parking in inconvenient or dangerous areas that impede the rights-of-way of pedestrians, cyclists, and devices or block ramp and curb access for people with disabilities.[20] Seattle has developed a policy for curbside management and to guide where dockless bicycles should be parked in urban areas (see case study on Seattle).

> As part of the Federal Transit Administration's Mobility on Demand (MOD) Sandbox, the Chicago Transit Authority (CTA) is currently partnering with Divvy bikes (a station-based bikesharing operator) to integrate bikesharing into their Ventra app and allow customers to pay for bikesharing use with their Ventra card (fare payment). Ventra cards store public transit credit for use on CTA and Pace in Chicago. The goal is for Chicago public transit riders to open the Ventra App, add public transit value to their account, pay for a bikesharing pass, go to a bikesharing station, and start cycling (Shaheen & Cohen, 2018).

A Case Study of Seattle's Dockless Bikesharing Curb Space Management Policy

Seattle's policy defines three key zones: 1) landscape/furniture zone, 2) pedestrian zone, and 3) frontage zone. Seattle requires dockless bicycles to be parked in the landscape/furniture zone and has painted labels on several curbs to highlight appropriate parking places. Additionally, Seattle prohibits bicycles from being parked on corners, driveways, or curb ramps and parking in a way that blocks access to buildings, parking meters, benches, bus stops, or fire hydrants (Shaheen & Cohen, 2018).

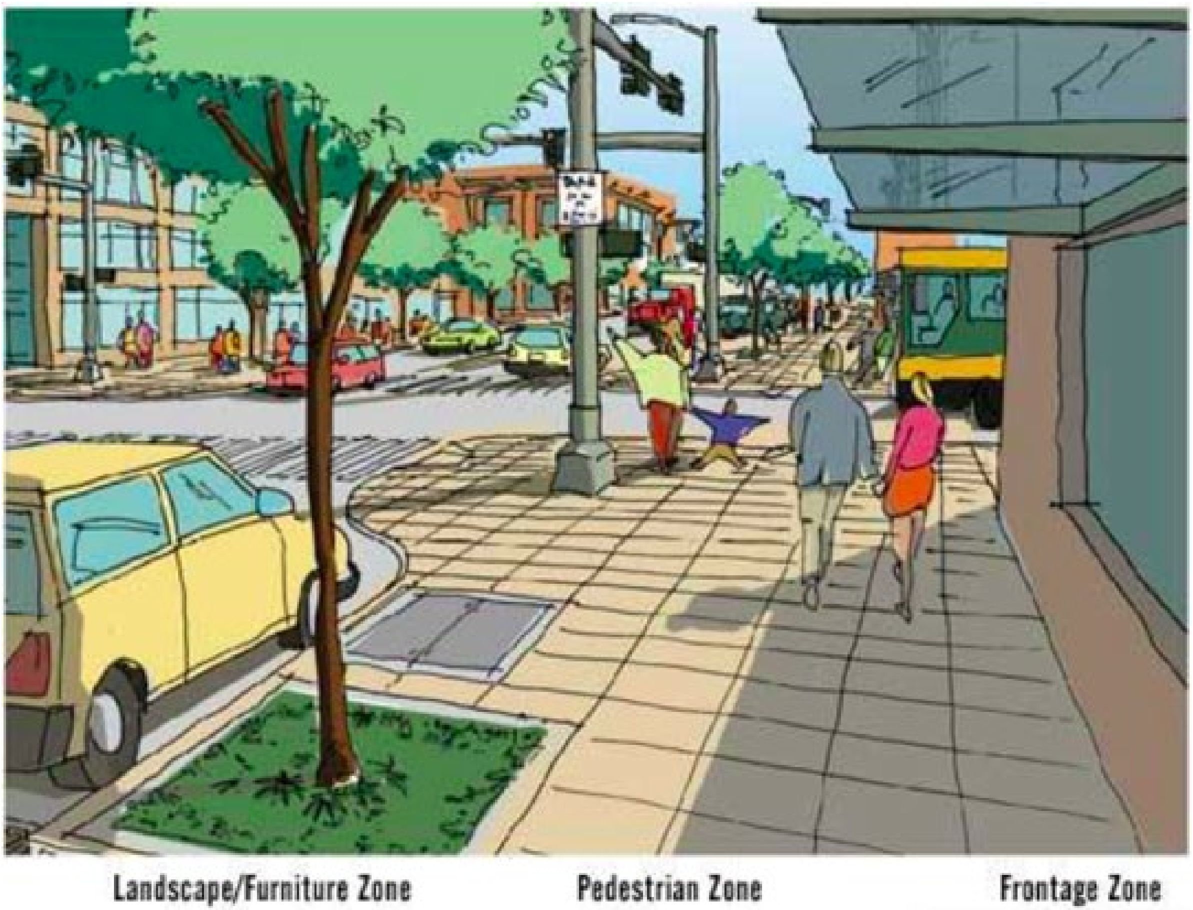

Figure 16. Seattle's Curb Space Zones

Source: City of Seattle

Figure 17. Seattle's Dockless Bikesharing Corrals
Source: Seattle Department of Transportation

Dockless Micromobility and Geofencing

In addition to curbside and micromobility parking policies, a number of cities also employ "geofencing" (i.e., the process of designating a certain region of a city or metropolitan area as off limits to prevent bicycles or scooters from being parked in distant, less urban environments).[21] For example, dockless operators in San Diego use geofencing to prohibit cyclists from parking and leaving their bicycles on Coronado Island. Similarly JUMP, acquired by Uber in Spring 2018, has geofenced Union Square in San Francisco to discourage bicycle parking in the busy pedestrian plaza.[22] Austin, Denver, and Kansas City are among cities that have specified geofencing as one of several options to implement mandatory controls on distribution and parking of dockless devices. In Denver's pilot, operators are at least required to geofence designated parking areas at bus stops and public transit stations. San Francisco has required that all permittees should be able to apply geofencing specifications for accepted and prohibited parking areas within one week's notice.

Dockless Micromobility and Enforcement Mechanisms

In the event that dockless equipment ends up in prohibited locations, a number of public agencies have developed fees and impounding policies to address these situations.[23] For example, Seattle requires dockless bikesharing companies to move improperly parked bicycles and to correct parking violations within two hours of a problem being reported during normal business hours. In Washington D.C., the National Park Service prohibits parking dockless bicycles in the National Mall and impounds illegally parked bicycles.[24] Universities have also levied impounding fees against operators for dockless devices that are illegally parked on their campuses. As of November 2018, Bird owed over $360,000 in fines to the University of Georgia for more than 1,000 impounded standing electric scooters.[25] Portland provides standing scooter operators with a time table in which they must respond to different complaints over obstructions in the rights-of-way (e.g., emergency versus non-emergency) before receiving a penalty fee. In Columbus, any dockless devices parked in one location for seven days without movement or any illegally parked device may be impounded at the operator's expense plus a retrieval fee. Most cities have opted to reserve the right to immediately revoke operator permits, if dockless devices are found as the source of repeated obstructions of the rights-of-way.

Dockless Micromobility and Rider Education

Typically, cities have made it a permitting condition that dockless device companies must educate potential riders about the appropriate use of their service in the local rights-of-way. Most cities also have some form of their own public outreach on how to safely use dockless modes. Seattle's dockless bikesharing 2018 to 2019 permit application requires operators to describe how they will inform riders about local helmet laws, traffic rules, and rules for parking bikes "safely and conscientiously." Seattle also stipulates that the rider education plan must also be consistent with the operator's proposal for an equity of access program. The city's public outreach includes a descriptive overview of a dockless bikesharing trip, guidelines for parking, and a detailed diagram of the rights-of-way with pointers for appropriate parking. San Antonio, for example, requires that all dockless device operator smartphone-apps must educate users on rider safety, including where riding is prohibited and how to park devices lawfully at the end of trips. San Antonio has produced an illustrated safety pamphlet available on the city website describing rider requirements, as well as phone numbers for reporting damaged or illegally parked devices. Cities have not required operators to extend their rider education programs to their social media accounts. One recent study noted that the dockless device operator Bird did not use their Instagram account to educate riders about the legal requirement and the possible safety benefit of wearing helmets.[26]

Figure 18. Rider Safety Educational Material Produced by Portland Bureau of Transportation

Caption: For its four-month standing electric scooter pilot, Portland used this graphic, along with other information available on its website, as part of its public outreach campaign. Other cities, such as Austin and San Antonio, have used a variation of this graphic. *Source: Portland Department of Transportation*

Dockless Micromobility and Equity of Access

Shared mobility has the potential to increase access to opportunities for many underserved populations, but it may also jeopardize access by not providing accommodations for vulnerable users and by reducing the viability of existing options they rely on.[27] Many cities have used regulatory frameworks for managing micromobility operators to ensure low-income and under-banked residents have equitable access to dockless devices.[28] Equity programs tend to include designated underserved areas for daily device distribution, a reduce-fare option for low-income residents, and an option for payment and device access that does not require a smartphone. Some equity programs include requirements or incentives for improving access for older adults or individuals who have visual, auditory, or physical disabilities. In its 2018 to 2019 dockless bikesharing application, Seattle grants operators who promise to deploy adaptive cycles with a fleet bonus of 1,000 devices plus preferential review on their application. Detroit mandates that operators deploy their devices in all seven city council districts, so residents in areas outside the downtown core have access near their homes.[29] Denver's equity program designates "opportunity areas" (i.e., sectors of the city where dockless devices must be deployed) and "high priority opportunity areas" (i.e., subsets of those sectors where the greatest number of vulnerable populations are located).

Dockless Micromobility and Pedestrian Safety

The rapid emergence of dockless devices, particularly standing electric scooters, has caused concern over pedestrian safety. According to the Washington Post, there are no official statistics describing how frequently pedestrians have been injured by standing electric scooters, but doctors interviewed in five cities indicated that badly injured pedestrians are entering trauma centers multiple times a week.[30] The Centers for Disease Control and Prevention (CDC) have partnered with Austin Public Health and the Austin Transportation Department (ATD) to conduct the first epidemiological study of the public safety impact of dockless standing electric scooters using the city's accident data from late-2018. The data sharing agreements put forward by local jurisdictions often require data about dockless accidents or crashes. As an example of one such report, Austin requires that the data provided should include the total number, severity, locations, and times of crashes. San Francisco has been building data systems to track injuries, both from riders and pedestrians, from all forms of micromobility, including dockless devices, as part of its Vision Zero transportation infrastructure safety initiative.[31] In 2019, cities are expected to adjust their regulations to respond to anecdotal public safety concerns. For example, Columbus is considering reducing its cap on dockless device speed from 15 mph (Department of Infrastructure Management, phone interview). While Denver restricted standing electric scooters to sidewalks in December 2018, it modified this regulation in January 2019 to require riders to use bike lanes whenever possible.[32]

BEST PRACTICES AND RECOMMENDATIONS

Cities can support dockless micromobility and minimize disruption by proactively developing policies to guide:

1. Identifying locations where bicycles and scooters should be parked;

2. Developing agreements with private operators that indemnify the public agency from liability for any loss or injury that could result from a dockless micromobility device operating or parked in the public rights-of-way;

3. Enumerating the enforcement procedures for illegally parked equipment (i.e., bikes and scooters), such as fines or impoundment;

4. Developing a process for requesting access to the use the public rights-of-way (i.e., curb space);

5. Identifying fees that should be charged or permits that should be issued for micromobility services to operate within a municipality;

6. Establishing standards for dockless micromobility parking signage and/or markings to identify proper parking areas; and

7. Developing data sharing requirements and/or impact studies as a condition to allowing micromobility services to park in the public rights-of-way.

SUMMARY

Key takeaways from this chapter include:

- Micromobility includes several different service models and travel modes that meet user needs. The B2C service model supporting dockless modes for standing electric scooters gained prominence in mid-2018 when companies rapidly expanded their deployment in American cities.

- IT-based micromobility began in 2007 with a station-based bikesharing system in Tulsa, OK. Between 2016 and 2017, the number of bikesharing bikes more than doubled from 42,500 to approximately 100,000. As of December 2017, a large majority (96%) of bikesharing trips were completed using a station-based bikesharing system, with the remainder (4%) of trips completed using a station-based bikesharing system.

- There have been diverse policy responses to the rapid emergence of dockless micromobility. Within the Smart Cities P2P Network, Austin, Denver, Portland, San Antonio, San Francisco, and Seattle have implemented pilot programs to study dockless devices. Other cities, such as Columbus and Dallas, have extended operating agreements with permitting conditions to dockless device companies. Detroit established guidelines for operators that defined legal access to the rights-of-way, incorporating common features, such as data sharing and equitable distribution of devices, without implementing a pilot or permitting process. All cities in the Network have required operators to provide data about trip activities to better understand how micromobility is being used on their city streets and to inform the iterative development of dockless device policies.

- Common micromobility issues facing cities are:

    - Multi-Modal Integration: Cities are deciding how to integrate dockless bikesharing and standing electric scooter systems with existing public transportation modes (e.g., light rail).

    - Curb Space Management: Cities are developing policies to prevent dockless micromobility equipment from parking in inconvenient or dangerous areas that would impede the rights-of-way.

    - Geofencing Implementation: Some cities are requiring operators to be capable of deploying location-based technology called “geofencing” that allows public agencies to set boundaries for operators where dockless devices can and cannot be parked.

- Policy Enforcement: In their permitting agreements with operators, many cities have reserved the right to revoke permits that provide access to the rights-of-way, if an operator's devices frequently violate regulations.
- Rider Education: Operators are typically required to educate potential riders about local rights-of-way laws and how to properly park their devices at the end of a trip. Cities are providing their own rider education materials as well.
- Equity of Access: Many cities have established equity of access programs to promote ridership among disadvantaged communities as mandatory components of operator applications. Key features of an equity of access program can include assigned deployment areas in underserved neighborhoods and affordable non-smart phone-based payment alternatives.
- Pedestrian Safety: Cities are responding to concerns over pedestrian safety through regulatory adjustments, such as lowering the maximum device speed, and collection of collision data from operators to better target policy interventions.

• Cities that have yet to develop a dockless device regulatory policy can minimize disruption to their streets by proactively developing regulations.

VIII. SUMMARY AND CONCLUSION

This report covers some of the most important findings regarding Smart Cities practices and implementation in the United States.

Smart Cities - the convergence of innovation, data, and digital technologies into a strategic approach that supports environmental sustainability, economic development, equity, efficient service delivery, and enhanced quality of life of individuals and society - is a concept that fosters innovation in public policy and administration to foster collaboration and partnerships that focus on people-oriented solutions.

This study makes a number of observations related to smart cities. Key findings from the expert interviews, stakeholder engagement process, and focus areas of the report include:

- Smart City Domains and the Pyramid of Innovation. A smart city represents an ecosystem of domains, pilots, innovations, and stakeholders working together at different city scales (from neighborhoods to regional levels). Smart cities are developing pilots and initiatives across seven smart city domains: 1) smart energy and environment; 2) smart transportation; 3) smart governance; 4) smart people; 5) smart living; 6) smart economy; and 7) smart connections. Fundamentally, smart cities are about innovation and collaboration that gets progressively more advanced to reach smart city attainment. This collaboration process can be described as a pyramid of innovation that starts with the individual innovator and becomes progressively more advanced, culminating in increased regional innovation and multi-stakeholder collaboration

- A Planning, Pilot Implementation, and Evaluation Framework for Smart Cities. Communities can employ a three-phase smart city framework to better understand community concerns, identify potential strategies, create institutional capabilities for collaboration, implement pilot strategies, and evaluate outcomes. Phase 1 is comprised of an initial assessment drawn from expert interviews and city demographics, design-thinking workshops, and problem statement development to better understand community concerns. Phase 2 includes a refinement and prioritization process and communities of practice to advance institutional capabilities. Phase 3 is focuses on pilot implementation and evaluation.

- Typology of Four Emerging Smart Cities and Regions. Communities pursuing smart city initiatives can be mapped across four different typologies to categorize a range of problems and strategies to facilitate innovation. The four smart city typologies include:

    - Tech-oriented communities and regions driven by technological innovation, often trying to address related challenges, such as housing affordability and cost of living issues;

    - Economic revival cities and regions reinventing their economies for post-industrial economic development;

    - Growth cities and regions that are growing economically and spatially, typically with fewer challenges associated with housing affordability and cost of living; and

  - Small and rural communities investing in placemaking and workforce development to retain talent.

- Smart cities are about solving problems. Stakeholders must understand the problem and how to identify the challenges. Who is the solution for? Why is it needed? How are things being done today? The problem-solving process is a critical ingredient to successful smart city outcomes. Stakeholders should never assume solutions before having an understanding of the problem that is trying to be solved.

- Smart cities should be “people” focused. There are many well-meaning smart city initiatives that stumble or fail because they forget to engage with the community that will be impacted by the potential solutions. Rather than focus on connected infrastructure, smart cities should focus on people-oriented outcomes such as: walkability, bike ability, air quality, affordability, and citizen empowerment. In other words, cities should not focus on technology but leveraging innovation and technology to improve community outcomes.

- Smart cities are about innovation. Innovation in management and the policy process is equally, if not more, important than technology. Public agency champions have to foster innovative management (both customer facing and internal) to create institutional capabilities to improve collaboration across organizational boundaries. This requires innovative organizational management and leadership. Additionally, policy innovation creates an enabling environment for policy experimentation, collaboration, and partnerships. There is also a back-to-basics recognition that technology should not be viewed as a solution but instead as an enabler to reducing inefficiencies and improving service delivery.

- Ensuring smart cities are equitable cities. There is an increasing concern that technology-enabled solutions may be leaving unbanked (households without access to a bank or credit card), underserved, and digitally impoverished (households without access to a smartphone or the Internet) communities behind. There is also worry that strategies may not be equitably serving all neighborhoods, economic strata, people with disabilities, and other groups. Finally, machine learning and artificial intelligence could be learning/replicating inequities in society and reiterating historic biases and injustice. There is a need to ensure that smart city solutions (processes, policies, and technologies) are accessible to everyone. The public sector has many roles ensuring equitable cities as a: facilitator, funder, regulator, and evaluator of smart city initiatives. For example, this can include facilitating partnerships, providing subsidies and grants, and developing proactive legislation and regulation that guides smart city initiatives toward equitable outcomes.

- Peer-to-peer collaboration. The stakeholder engagement process revealed that there is a lot of interest in collaboration, identifying case studies and best practices, and developing an implementation strategy to solve a variety of challenges. Allowing public agencies to engage with each other in structured and non-structured environments, outside of the typical smart cities conference environment and not in the presence of private sector vendors, there is an immediate benefit to being able to candidly share what works and what does not work with their peers in other cities and public agencies.

- Breaking down silo barriers is critical. Organizational and departmental barriers stifle innovation and create inefficiencies. Breaking down organizational silos is needed to foster innovation, knowledge, and collaboration across agencies but with an array of community stakeholders such as: non-profits, the private sector, and others. There is also a recognition of the need and importance of partnerships and that no one organization can do everything themselves. Similarly, the private sector is also recognizing there are opportunities through partnerships.

- Regionalization. The term “smart cities” implies that it is just about the city, but the authors’ research revealed that the success of smart city initiatives depends on how the city engages with the region on strategies. Challenges that are often thought to be typical of the urban environment are being pushed out to suburban and rural communities. For example, affordability and displacement in some communities is forcing the poor to the suburbs where there is also a need for smart city approaches.

- Organizations require strong 360◦ leadership. Smart cities require omni-directional leadership vertically through an organization and laterally across agencies and stakeholder groups. This requires executive-level champions of innovation and staff that are empowered to support and carry initiatives forward. Additionally, distributed leadership across organizations is required to foster partnerships and break-down silos.

- Regional implementation of smart cities programs often varies by organizational structure, strong leadership, and champions. In all cases, strong leadership is required to maximize smart city opportunities. However, strong leadership and the organization(s) leading smart cities can vary a great deal (e.g., strong mayor vs. city manager; city-led versus public transit agency-led versus metropolitan planning organization-led initiatives, etc.). The presence of multiple champions encourages innovation, helps break down silos, and creates institutional resiliency that can transcend political and staff changes.

- Big data and shared micromobility represent two notable challenges smart cities are negotiating. The stakeholder engagement process involved in this study revealed that smart cities are keenly interested in understanding and leveraging big data including: 1) identifying different data sources; 2) understanding how to manage the data; 3) mitigating privacy concerns; and 4) initiating data projects (e.g., data agreements, data sharing, and data repositories). In addition to big data, shared micromobility (e.g., scooter sharing and bikesharing) emerged as another primary focus area including how to regulate it, ensure public safety, and incorporate it into the mobility ecosystem.

- *Big Data:* Public agencies are commonly using big data for a variety of purposes including: 1) augmenting public safety response through predictive policing; 2) reducing traffic congestion through active transportation demand management operations monitoring; 3) responding to transportation safety trends (e.g., accidents and fatalities); 4) improving municipal service delivery; and 5) supporting sustainability initiatives.

- *Shared Micromobility:* The growth of bikesharing (station-based and dockless) and scooter sharing is impacting a number of cities. Common issues raised by cities include: 1) the need for public policy to manage curb space; 2) issues with dockless equipment blocking American Disability Act (ADA) access (e.g., scooters or bicycles blocking wheelchair use of curbs and ramps); and 3) the need to integrate shared micromobility into comprehensive transportation planning (modeling, plans, urban design, trip planning, integrated fare payment, etc.).

- Preparing the workforce for an automated future. There is a lot of concern that automation will displace jobs and the vast impacts this will have on citizens and cities, including employment and economic development. There is a desire for public agencies to proactively prepare for automation and leverage the potential positive impacts. There is also a recognition of the need for workforce development and ensuring that training and job placement outpaces automation.

One size does not fit all. Smart cities vary by size, region, economic, cultural, and other characteristics. Across the United States, cultural attitudes toward public transportation, shared mobility, and urban density vary considerably. To quote Former Speaker of the House Tip O'Neill: "all politics is local." The characteristics of smart cities are truly local and individualized, often characterized by local government structures and politics. There are some emerging smart city typologies.

APPENDIX A: EXAMPLES OF THE COMMUNITY OF PRACTICE DEEP DIVES CONDUCTED BY SMART CITIES LAB AND TEXAS INNOVATION ALLIANCE APRIL 2018 – MARCH 2019

1. What is the future of dockless bikes and scooters and what are some of the best practices to address shared micromobility?

2. How do we move to an open, non-proprietary payment platform to enable the seamless mobility?

3. Can or should our cohort develop a common approach to community engagement?

4. How do we serve residents in low-density, high-need areas so that it is cost-effective for residents as well as public transit agencies?

5. How are our cities and regions improving access to prenatal care to reduce infant and maternal mortality?

6. Are scooter injuries a public health concern?

7. How do we electrify multiple-unit developments (MUDs)?

8. What are some of the best practices around community engagement?

9. What is the role of public agencies in automated vehicle readiness?

10. Can public agencies address transit deserts by providing mobility options to residents in low-density, high-need areas?

11. Is an electric carshare program viable in underserved neighborhoods?

12. What are public agencies doing to get our infrastructure ready for connected vehicles?

13. What is the role of transportation network companies (TNCs) in providing access to medical care?

14. How should we think about automated vehicles for aging and disability populations?

15. How cities and regions can utilize the PUC process to install more charging infrastructure?

16. How can cities and regions develop innovative approaches to tackling first and last mile mobility challenges?

17. How can cities and regions collaborate to create a viable urban data lake for emerging transportation data?

18. What are the impacts of DC Fast Charging on TNCs?

19. How do we do a better job engaging the public on electrification DC Fast Charging Engaging the Public on Electrification

20. Can fuel efficient truck platooning and connected vehicle technologies be used in places other than highway corridors?

21. What are our public agencies doing to provide better access to medical care?

22. How can signal phasing and timing (SPaT) help us move people and goods more efficiently?

23. What are cities doing to manage TNC pickup and drop-off in congested areas?

24. What are the strategies for seamlessly integrating an automated, connected, electric, and shared future?

25. How are transit agencies approaching payment and ticketing?

26. With the explosion of real time data how are public agencies addressing potential data security issues?

27. Connected vehicle use cases and the data management strategies needed to improve economic development and mobility.

ABBREVIATIONS AND ACRONYMS

ACS	American Community Survey
AAPOR	American Association for Public Opinion Research
EPA	Environmental Protection Agency
MPG	Miles Per Gallon
RDD	Random Digit Dialing

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