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Benchmarking “Smart City” Technology Adoption in California: Developing and Piloting a Data Collection Approach

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Benchmarking "Smart City" Technology Adoption in California: Developing and Piloting a Data Collection Approach

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16. Abstract

In recent years, "smart city" technologies have emerged that allow cities, counties, and other agencies to manage their infrastructure assets more effectively, make their services more accessible to the public, and allow citizens to interface with new web- and mobile-based operators of alternative service providers. This project reviews the academic literature and other sources on potential strengths, weaknesses, and risks associated with smart city technologies. No dataset was found that measures the adoption of such technologies by government agencies. To address this gap, a methodology was developed to guide data collection on the adoption of smart city technologies by urban transportation agencies and other service providers in California. The strategy used involved webscraping; interviews with experts, public agency, and senior level staff; and consultations with technology vendors. The approach was tested by assembling data on the adoption of smart city technologies in California by municipalities and other local public agencies.

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Executive Summary

Executive Summary

In recent years, “smart city” information and communication technologies (ICT) have emerged that could potentially allow cities, counties, and public agencies to manage their infrastructure assets more effectively, plan for preventive maintenance, monitor security, and make their key public services more accessible to the public (Hall 2000). Common transportation examples include infrastructure-to-vehicle communications for autonomous vehicle systems, automated sensing of bicyclists and pedestrians, and mobile- and web-based interfaces that allow citizens to access alternative service providers, such as transportation network companies (e.g., Uber, Lyft). Some additional consumer applications include home energy and water consumption monitors, weather and emergency warning systems (e.g., Amber alerts), and digital service requests/billing.

To better understand the circumstances under which these smart city technologies are adopted, and to allow local public agencies to learn from each other’s experiences with such technologies, we developed a methodology for collecting data on the adoption of these technologies by local jurisdictions across the state of California. In particular, the benchmarking strategy we developed can identify 1) which types of technologies are being adopted more and less frequently by local public agencies; and 2) which California public agencies — varying in population, population density, geography (rural versus urban) and other characteristics — have adopted new technologies most. We then piloted this methodology by collecting data on technology adoption in the transit, water and sanitation, and security sectors in California. Within these three sectors, our pilot study examined multiple types of technology presently at different stages of adoption and reflecting a broad range of goals identified in the literature, including sustainability, resilience, social equity and justice, transparency, citizen participation, cost savings, and efficiency. This report describes the data collection approach and outlines the outcomes of that pilot study.

Our data collection primarily involved webscraping, which is an automated data collection technique to extract information from web pages and apps. This approach is particularly effective for collecting information about the uptake of consumer-facing technologies where information about adoption is visible on websites or within apps accessible to members of the public. Future work funded by a follow-up UC ITS grant will include surveys and interviews; this approach is more effective in cases where there is a high degree of market fragmentation among vendors, or where vendors are reluctant to share data on their customers. The full results generated by this research on technology adoption in California is publicly available through a website developed specifically for this project and related ongoing work at <connectedgov.berkeley.edu>.

As part of the test study, we conducted a case study of one important new transportation application, General Transit Feed Specification (GTFS), an open-source data format through which public transportation agencies share information about routes and vehicle stop and station arrival times. Based on the data collected, we identify two circumstances under which transit providers are more likely to adopt GTFS, namely 1) the agency is reasonably large and operates in an urban area, and 2) it is an independent public agency, as opposed to a department within a local government. We suggest some reasons why this is the case. Our analysis also highlights the critical importance of real-time GTFS-data feeds during the COVID-19 pandemic when a large number of low-income workers needed up-to-date information on transit schedules to report to work on time. This demonstrates the sort of analysis that can be carried out with the data gathered for the rest of the twelve applications examined in the pilot study, as well as other smart technologies using the methodology presented here.

The methodology outlined in this report can further be used to develop a comprehensive and sustainable long-term data-collection strategy that will enable engineers, social scientists, policymakers and members of the public to learn about the adoption of smart city technologies, as well as the potential benefits and risks associated with adopting them. Such analyses can allow researchers and policymakers to identify jurisdictions that are more or less likely to possess access to technologies that could potentially improve the transparency or efficacy of certain services. Analyzing this data in conjunction with community demographic information could also reveal whether certain communities are more likely to be subject to surveillance or vulnerable to privacy concerns due to the adoption of new technologies. Data collected according to the methodology proposed here could be verified through interviews and ethnographic observation, a process which could not only yield important information about data accuracy, but also provide insights into the implications of the patterns observed. Results of these analyses can then be disseminated and discussed in public and research venues, as well as in educational and workforce development settings.

We further hope that the approach outlined here will also lay the groundwork for a future proposed membership program in which participating cities, special districts, and utilities provide information about technology adoption on an on-going basis in order to learn from one another and contribute to broader understanding and further research about technology adoption by other agencies in California.

Contents

The Case for Benchmarking Smart City Technology Adoption

The policy world is abuzz with discussions of "smart city technology." Conferences and consultants tout the potential advantages of transparency-oriented technologies like open data portals and digital feeds for public meetings, as well as technologies poised to improve conservation efforts, like smart metering. Other proponents of smart city technologies focus on disruptive technologies like internet-enabled ride-sharing firms. Numerous consultancies and organizations have created "smart city" indices to compare relative levels of uptake of such technologies. As we will show below, these existing efforts fall short in important ways: they lack transparency, and often conflate technology adoption with measures of social and economic conditions. In this section, we will discuss existing smart city indices and their shortcomings. We start, however, by defining smart city technologies and explaining their main features.

What Are Smart City Technologies?

The term "smart city" is generally used to describe the deployment of information and communication technologies (ICT) to improve urban services and infrastructure (e.g., Chourabi et al. 2012). Smart city technologies, then, are technical systems that are designed to improve the efficiency, transparency, or other aspects of the performance of urban services and infrastructure. They typically draw on new types of data, such as data collected through video feeds, sensors, or crowd-sourced information from individuals. Commonly-cited examples include crowd-sourced forms of feedback on public services (e.g., online complaint systems), open data portals, emergency alert systems that send messages to cell phones, smart metering systems, CompStat and other systems of predictive policing, and satellite water leakage detection systems.

Technical fields — including engineering, computer and data sciences, and others — have developed a vast amount of applied research aimed at developing new smart city technologies, applications, algorithms, or assessing the technical challenges of applying them. This section briefly reviews the technical literature on smart city technologies and applications. The literature on specific technologies is extremely vast,[1] covering a wide range of applications in urban contexts and highlighting potential

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[1] Among the many specific topics discussed in the technical literature, for example, scholars have described different standards of Wi-Fi connectivity and Internet networks needed to enable smart city applications (Khorov et al. 2015). Others proposed a system for real-time processing of big data generated by smart homes, parking structures, pollution, and vehicle data (Rhatore 2016). Still others proposed using sensor infrastructure to create pollution-free routes across cities (Ramos et al. 2018). Additional examples include an algorithm proposed for maximizing the coverage of closed-circuit television (CCTVs) under budget constraints (Jun et al. 2017), an algorithm for regulating traffic signals in dynamic traffic conditions (Li et al. 2019), and an overview of the use of sensors and sensing systems to improve the performance of power grids (Morello et al. 2017).

positive outcomes in traffic, service delivery, waste management systems, and infrastructure provision, among others. While it is beyond the scope of this report to offer a comprehensive review of the literature on specific technologies, this review focuses on identifying key technical frameworks or classifications that allow us to have a more nuanced understanding of differences between various types of smart city technologies in terms of their functions and vulnerabilities.

In broad terms, the technical literature on smart cities can be organized into subsets that focus on different technology-related concepts and devices, such as Internet of things, big data, sensors, or e-government, as well as on different types of applications, such as traffic management, public safety, or citizen engagement. The most used framework for classifying smart city technologies is based on “layers.” This framework reflects more accurately the architecture of the Internet of things (IoT) than other systems. Each layer refers to a particular step in dealing with information: the four-layer model, for example, includes 1) a *sensing* layer, 2) a *transmission* layer, 3) a *processing* layer, and 4) an *application layer* (Liu and Peng 2014). Some authors use different nomenclatures that refer to similar ideas: Yin et al. (2015) use the same four-layer model, calling them the data acquisition layer, data vitalization layer, common data and service layer, and domain application layer; others use a three-layer model, organized around a perception layer, a network layer, and an application layer (e.g., Silva et al. 2018; Lin et al. 2017). Balakrishna (2012) uses the terms gather plane, share plane, and govern plane; and, more recently, some studies have suggested the use of a five-layer architecture, including a perception layer, a network layer, a service management layer, an application layer, and a business layer (e.g., Silva et al. 2018).

In the framework in Table 1, each layer refers to different types of technologies. The *sensing layer*, where information is captured or acquired, relies on components such as RFID tags, sensors, and cameras. The *transmission layer* includes networks and communications protocols that can transfer data electronically from the sensing device to their storage and processing stages, such as Bluetooth, WiFi, LoRaWAN, 3G, among others. The *processing layer* refers to those technologies involved in supporting how data is stored and analyzed, such as service support platforms and cloud computing. Lastly, the *application layer* is the interface with the “real world,” where monitoring, control, and other actions occur, drawing on one or multiple types of the new data collected.

Table 1. Types of smart city technology “layers” and examples

Type of New Technology Layers	Examples
Sensing layer: data collection technologies	RFID tags Sensors Images from camera (e.g., CCTV) Smartphone data
Transmission layer: improved communication systems and networks	Broadband and fiberoptic cables Radio frequency identification Wireless sensor networks
Processing layer: data management and analysis systems	Cloud storage Cloud computing Artificial intelligence
Application layer: applications that serve as interface with users and/or providers	Open data portals Phone apps Provider control panels/dashboards
***Applications* in a variety of functional areas**:	
Security	Real-time crime mapping Disaster early-warning systems Predictive policing
Mobility	Digital public transit payment Intelligent traffic signals Car sharing
Energy	Smart streetlights Dynamic electricity pricing Home energy consumption tracking
Water	Leakage detection and control for utilities Water consumption tracking
Citizen engagement	Civic engagement platforms Digital service requests/billing

Source: Developed by authors, building on Liu and Peng (2014) and McKinsey Global Institute (2018).

Further, technical scholarship on smart cities discusses in more detail varying risks and challenges posed by the application of specific technologies. For example, scholars have discussed harms associated with algorithmic bias in technologies such as crime mapping and predictive policing (Benjamin 2019, Jefferson 2018, Noble 2018). In the field of transportation-related technologies, recent research has found challenges in autonomous vehicle technology recognition and response to pedestrians, bicyclists and other objects in vehicle pathways (Taeihagh and Si Min Lim 2019), as well as social inequities in the affordability, distribution and accessibility of recent new services offered by transportation network companies (e.g., Uber, Lyft) and “micromobility” (shared bicycles and scooters) (e.g., Shaheen and Cohen, 2018), and in the broader utilization and uptake of autonomous vehicles (Sheller 2008).

Additionally, scholars have raised concerns regarding privacy and other cybersecurity issues in the context of data sharing and data mining, network security risks, the need for establishing trustworthiness in data sharing practices, the use of artificial intelligence when operating infrastructure control systems, and the possibility of cascading failures in smart city networks (Braun et al. 2018).

These concerns are echoed in studies that focus on certain smart city technologies. For example, in a broad analysis of the use of big data in different urban projects, Lim et al. (2018) present evidence that concerns with privacy are a crucial barrier for citizens in adopting a proposed public health service. In the field of smart transportation systems, Beck (2017) observes that security concerns are often underappreciated by cities embarking on smart city programs: only 19 out of the first 32 applications to the U.S. Department of Transportation's Smart City Challenge voiced concerns about security risks. Medaglia and Serbanati (2010) look into the challenges of privacy and security in networks (RFID and WSN) that allow for the collection of information in IoT systems. Bennati and Pournaras (2018) acknowledge that privacy is a key challenge for smart cities, and propose a system to enhance privacy through group-level aggregation of data collected by sensors. Other examples of systems proposed to address privacy concerns can be found in Li et al. (2016), who analyze cybersecurity risks in smart traffic light systems and develop a method to mitigate vulnerability to cyber-attacks; and in Whittington et al. (2015), who examine the potential for security breaches in city-based open data initiatives and develop recommendations on data protection and privacy.

Thus, the issues vary significantly depending both on the particular technology and on the sector of application. Helpful analyses of how risks vary according to the type of application can be found in Khatoun and Zeadally (2017), while Kitchin and Dodge (2019) offer a summary of risks focusing more on different technological systems. Khatoun and Zeadally surveyed key security and privacy concerns in sectors including transportation, government, healthcare, and energy, among others. Their review demonstrates how threats vary significantly depending on the sector: while risks to transportation technologies might include tampering with vehicles' breaks and engine, the energy grid might be more susceptible to denial-of-service attacks, or government-related technologies can be more often targeted for identity theft. The authors suggest countermeasures to improve the cybersecurity of these smart city applications, ranging from staff awareness training to two-factor authentication practices. Similarly, Kitchin and Dodge also survey risks of cyberattacks and mitigation strategies, but they focus on types of smart city "solutions," such as IoT, SCADA (Supervisory Control and Data Acquisition), or communication technologies and protocols. This perspective allows them to identify complementary explanations for varying levels of risks to different smart city technologies, including the size of attack surfaces (IoT architectures, for example, have larger attack surfaces than SCADA systems) and interdependencies among different systems.

Indices and Rankings

While there have been numerous data collection efforts regarding smart cities, they have typically taken the form of non-transparent city ranking exercises utilizing data that is not publicly available and blend normative assessments with empirical data on technology adoption. As a result, smart city indices and rankings have been a contentious topic within the scholarly and policy literature on smart cities. Motivations for indices and ranking development vary widely from seeking to highlight broader public policy goals on key issues such as climate, economic competitiveness and mobility to consultancies seeking to establish and promote expertise and competitive advantage in the realm of smart cities. In particular, some scholars see rankings efforts in a positive light, suggesting that, by enhancing city competition, they work as a productive instrument for strategic planning, since they allow local governments to detect strengths and weaknesses of their cities, and drive policymakers to improve their goals, actions, and decisions (e.g., Giffinger et al. 2010; Giffinger and Gudrun 2010; Albino et al. 2015; Escolar et al. 2019). Others view rankings — and smart city indicators more broadly — from a critical perspective, suggesting that the quantitative assessment of "smartness" or "smartmentality" works as a mechanism for political legitimization and neoliberal (private sector) normalization that reframes what are important problems to be addressed by urban governments (e.g., Vanolo 2014; Kornberger and Carter 2010).

Broadly speaking, an index or ranking seeks to assess the "level" of a smart city based on a set of dimensions and indicators. Academic studies that examine and propose frameworks for smart city rankings vary in the definition of smart city used to structure data collection efforts. In their study of different city rankings, Giffinger et al. (2010) identify six key components that commonly characterize the level of a city's "smartness" in such rankings: 1) competitiveness, 2) social and human capital, 3) participation, 4) transport and ICT, 5) natural resources, and 6) quality of life. The authors then detail specific indicators under each category, and propose a ranking of 70 European mid-sized cities; the cities ranked in top positions are Luxembourg and other Scandinavian, Dutch, and Austrian cities. Lombardi et al. (2012) propose a similar system composed of five dimensions: 1) smart economy, 2) smart people, 3) smart governance, 4) smart environment, and 5) smart living; however, the authors combine these dimensions with four actors — university, government, civil society, and industry — to arrive at their proposed specific indicators. Different from Giffinger et al.'s and Lombardi et al.'s systems, Priano and Guerra (2014) propose a framework for measuring the "intelligence" of cities that is based less on standardized indicators, and more on the relation between problems identified, solutions proposed, and effectiveness, including perception from citizens. Finally, Perboli et al. (2014) propose to focus on smart city projects, instead of cities, suggesting a taxonomy for comparison based on multiple dimensions and related specifics: for example, in terms of objectives, they propose to assess whether the project addresses issues such as e-governance, water management, or sustainable energy; or, in terms of tools, e.g., if it uses for cloud computing, innovative sensors, or smart grids.

Similar to ranking frameworks proposed within the academic literature, rankings constructed by consultancies and other organizations also exhibit a wide variety of criteria and indicators. An online search for relevant smart city indices relying upon transparent formulae and that can be accessed free or charge[2] yielded six indices[3] (refer to Table 2). In most cases, private companies — either consultancies or firms in a smart city-related industry — developed or sponsored these indices, with

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[2] There are multiple rankings that can only be accessed after purchase, targeting businesses as clients; one example is the *ABI Smart City Ranking*.

[3] The search was not exhaustive; searching was concluded when news articles that routinely referred to the same indices were consistently found. An additional index is the Future Mobility Competitiveness Index (FMCI), which looks at transportation-related technologies and infrastructure, rather than at smart city services more broadly. FMCI was developed by the Oliver Wyman Forum, an international consultancy with offices in 30 countries, in partnership with UC Berkeley Professor Alexandre Bayen.

the exception of the *IESE Cities in Motion Index*, developed by IESE Business School's Center for Globalization and Strategy at the University of Navarra in Spain (with IESE as Instituto de Estudios Superiores de la Empresa in Spanish). The *Smart City Index 2018*, for example, was developed by EasyPark, a European company headquartered in Sweden that offers smart parking services. The *Smart City Strategy Index*, another example, was developed by Roland Berger, a German management consulting firm. The indices vary significantly in terms of the pool of cities analyzed and criteria used. Some indices ranked 500 cities (the resulting ranking has less known small/midsized cities in top positions), while others pre-selected a smaller pool of cities for analysis (ranging from 50–165 cities). The methodology underlying these indices reflects a neutral to positive stance relative to the technologies included in the rankings. The indices also are ahistorical in that they do not contain information about existing and past systems of inequities and challenges, and typically do not consider the potential harms or risks that could stem from technologies such as those identified in the literature discussed here.

Table 2. Rankings and indices of smart cities

Ranking/Index	Author	Range	Top three cities
Smart Cities Index 2018	EasyPark (smart parking services firm)	500 cities	1. Odense, Denmark 2. Aalborg, Denmark 3. Oulu, Finland
IESE Cities in Motion Index (CIMI)	IESE Business School's Center for Globalization and Strategy (university research center)	165 cities	1. New York, United States 2. London, United Kingdom 3. Paris, France
Top 50 Smart City Government	Eden Strategy Institute and ONG&ONG/OXD (consulting and design firms)	140 cities	1. London, United Kingdom 2. Singapore, Singapore 3. Seoul, South Korea
Global Smart City Performance Index	Juniper Research (research firm), sponsored by Intel (tech firm)	20 cities	1. Singapore, Singapore 2. London, United Kingdom 3. New York, United States
Smart City Strategy Index	Roland Berger (consulting firm)	87 cities	1. Vienna, Austria 2. Chicago, United States 3. Singapore, Singapore
Smart City Report	McKinsey Global Institute (research and consulting firm)	50 cities	*Strength of smart city technology base:* 1. Singapore, Singapore 2. New York City, United States 3. Seoul, South Korea *Deployment of smart city applications:* 1. London, United Kingdom 2. New York City, United States 3. Los Angeles, United States

Source: Developed by authors.

The smart city indices and rankings surveyed partially fit the typology developed by Giffinger and Gudrun (2010), which include five types of rankings: 1) rankings commissioned by economy/consulting-oriented firms, with a worldwide scope, 2) rankings commissioned by expert panels or private research institutes, with various spatial scopes, but mostly worldwide, 3) rankings compiled by magazines or non-governmental organizations without sponsorship, usually focused on a country or continent, 4) rankings by universities or economic research institutes with different sponsors, also usually focused on a country or continent, and 5) special/exceptional cases not included in previous categories. According to the authors, and reinforced by the findings, these ranking types are associated with different levels of transparency in documentation and analytical rigor (e.g., commissioned rankings have less transparency). The *Top 50 Smart City Governments* ranking, for example, was compiled by consultancies and design firms and includes a set of ten generic criteria, without presenting how measures were calculated or describing the data upon which it is based, which makes it hard to assess the quality of the data and analysis. On the other hand, documentation for the university-based ranking *IESE Cities in Motion Index* presents detailed criteria and indicators, and describes the sources of the data upon which it draws.

In terms of criteria, most rankings analyzed here use a broader and more comprehensive notion of a "smart city," incorporating not only indicators on the use of technology or ICT, but also more general economic, human capital, and living standard indicators — in line with proposals from the literature on smart city rankings and echoing some of the definitional debates discussed in the first section. They usually group indicators into broader categories, such as "transport/mobility," "governance," "sustainability," "economy," and "public safety" among others. These categories mix indicators of technology with more general ones: for example, the "public safety" category from the *Global Smart City Performance Index* accounts for "smart street lighting" and "intelligent video surveillance" on the one hand, and "violent crime rate" and "police force size" on the other hand.

A smaller subset of rankings focuses more specifically (or exclusively) on the use of technology and ICT; coincidently, they are the ones developed by management consulting firms (the *Smart City Strategy Index* by Roland Berger and the Smart Cities report by McKinsey Global Institute, MGI). Since they provide more detail about smart city technology adoption, they typically present data for a smaller pool of cities than other indices. The report from MGI, particularly, offers a long and diverse list of technology and ICT-related initiatives; diverse examples include "real-time crime mapping" in security, "digital public transit payment" in mobility, "dynamic electricity pricing" in energy, "smart irrigation" in water, "optimization of waste collection routes" in waste, "digital business tax filing" in economic development, and "local civic engagement applications" in engagement and community.

Recently, international standardization bodies have begun to establish standards related to adoption of smart city technologies. Most notably, the International Standardization Organization (ISO) released ISO 37120 with indicators for city services and quality of life in sustainable cities and communities, and ISO 37122 with indicators to measure progress towards a smart city. ISO 37122 includes a broad range of indicators in sectors such as the economy, education, energy, finance, governance, health, housing, safety, solid waste, telecommunication, and transportation. While most of the specific indicators refer to the use of sensors and other information and communication technologies (e.g., coverage of digital surveillance cameras, online access to public services, or real-time water quality monitoring), there are also indicators not directly related to smart technologies (e.g., percentage of treated wastewater being reused or number of citizens engaged in planning processes). Huovila et al. (2019), in one of the few studies about these indicators, point out that 73 percent of ISO 37122's indicators focus on "hard" smartness (i.e., ICT, technology, and physical infrastructure) and 32 percent on ICT specifically. The use of standards from ISO allows cities to apply for external certification of smart city efforts, but the ISO does not collect data from cities themselves or offer a comparison tool such as a comprehensive index. Certification is voluntary and data on whether or not particular cities have met particular indicators is not available to the public.

Stepping back, this review of existing smart city indices highlights the absence of an index that focuses specifically on the adoption of smart city technologies (rather than mixing technology and social and environmental indicators), that is constructed with transparent formulae using data that is shared with the public, and that is available for a large set of jurisdictions rather than just a small set of large cities. This is the gap that this benchmarking effort, focused on the adoption of smart city technologies by a comprehensive set of local public agencies in California, aims to fill.

Our Novel Methodology for Benchmarking Smart City Technology Adoption

This section describes our novel methodology for measuring the adoption of smart city technology in California. Given the shortcomings of the existing smart city indices and rankings described above, we develop a methodology that involves collecting data about the adoption of multiple types of smart city technologies by local public agencies, and compiling this data in a fashion that allows members of the public to aggregate data according to their own criteria. We compile data on the adoption of specific technologies by individual jurisdictions with functional responsibilities in particular policy areas. It focuses on the "application layer" previously discussed and uses methods described below, and is offered to the public in a disaggregated format (To access data collected thus far, see the project website: at <connectedgov.berkeley.edu>).

While this approach has been developed and piloted in California, it can serve as a blueprint for data collection efforts spanning the United States or more broadly. In consultation with industry stakeholders and subject matter experts, the authors developed and piloted an approach that also could be used to assemble a dataset to provide publicly available, comprehensive information on 1) which types of technologies are being adopted; and 2) which California public agencies — varying in population, population density, geography (rural versus urban) and other characteristics — have adopted new technologies most frequently.

For this SB 1 pilot project, we piloted this approach by collecting data on technology adoption in the *transit, water and sanitation, and security sectors* by California local public agencies. Adopting a comparative approach including not just transportation allowed them to generate data indicating whether or not local public agencies providing transportation services adopted new technologies more or less frequently than those working in other sectors, and whether or not factors associated with adoption in the transportation sector are also associated with uptake in other sectors. In all three sectors, decisions about adoption are primarily made by local public agencies such as cities, counties, and special districts. Public security is a sector in which many new smart city technologies have also emerged, and in which technology adoption is less tied to expenditures on hard infrastructure. However, their adoption is increasingly of grave public concern because of systemic racism, police brutality and structural inequities alongside issues of privacy and surveillance (Summers, 2020). Water and sanitation, in contrast, is a sector in which technology adoption is less likely to have high salience with the public, but which involves significant hard infrastructure like transportation.

Identifying Smart City Technologies

We developed an initial database of indicators for levels of adoption of smart city transit, water and sanitation, and security technologies by city governments, as well as other public and private agencies in California. In doing so, we drew on Hall's definition of smart city technologies as those that use real-time data to allow a city or service provider to "monitor the conditions of all of its critical infrastructures, including roads, bridges, tunnels, rail/subways, airports, seaports, communications, water, power, even major buildings, [to] better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens" (Hall 2000). As noted in the literature review (see Appendix A), there is a broad range of perspectives on the relative utility and risks associated with individual smart city technologies. By collecting data on a range of different technologies intended to serve different purposes, and providing access to this data in a disaggregated fashion on the project website, we are providing members of the public the opportunity to consider individual technologies that may be promising or concerning, and come to their own conclusions about the implications of any patterns they observe.

We chose to measure the adoption of applications that *utilize* new types of data that have been collected (the "application layer" discussed above and listed in Table 1), such as intelligent traffic signals, rather than merely report information on the existence of new forms of data collection (e.g., the prevalence of sensors on buses and traffic signals, which would be included in the "sensing layer"). This is because applications using new types of data very likely reflect broader patterns of technology adoption; they depend upon the existence of the collected data and communications systems, which generally include other layers such as sensing, processing and transmission (see Table 1). For example, a citizen-facing application that provides real-time information about the arrival of public transit can only exist once the real-time data is collected and successfully communicated to a central node.

We developed a list of candidate applications from the "application layer" by reviewing existing reports of technology adoption and conducting interviews with experts in academia, the private sector, and government (Table 3). This list was developed in a way that generated variation across two dimensions for the dataset (Table 4). We then chose twelve candidate applications for which data is being collected (Table 5, below). First, they sought to include applications across a range of objectives used to justify the adoption of smart city technologies, including sustainability, resilience, social equity and justice, transparency, citizen participation, cost savings, and efficiency. We also include applications that are currently at different levels of adoption building from Rogers' "S curve" of adoption discussed in Appendix A (see Figure A1). For example, with respect to transportation, they include the publication of real-time general transit feed specification data (GTFS), which is arguably at an early stage of adoption. We also include the adoption of fleet-management technology, which is far more widespread. Collecting data across three sectors — transportation, public security, and water and sanitation — allows us to assess the extent to which public agencies are adopting smart city technologies more or less frequently than service providers in other sectors.

Table 3. Candidate applications for data collection by sector

Security	Mobility	Water and Sanitation
Body cameras Crowd management Disaster early warning systems Security alerts Emergency response optimization Gunshot detection Home security systems Personal alert applications Predictive policing Real-time crime mapping Smart surveillance License plate readers Real-time collision reporting Mobile citations	Autonomous vehicles Bike sharing Car sharing Congestion pricing Demand-based microtransit Integrated payment for transit E-hailing Integrated platform providing information about transit options GTFS feed provision and use Predictive maintenance Real-time road navigation Real-time public transit information Smart parcel lockers Smart parking Electric vehicle charging stations Geofencing Pay-as-you-go insurance Ramp metering Intelligent traffic signals Parcel load pooling Fleet management systems	Remote data entry for employees GIS mapping Leakage detection and control Satellite leakage detection and control Smart irrigation-incentives for consumers Water consumption tracking Water quality mapping Connected trash cans Digital tracking and payment for waste disposal Waste collection route optimization Heavy rain and flood control management Smart metering (feedback for consumers) Flood alert systems

Table 4. Examples of different purposes served by smart city technologies

	Transparency	Efficiencies	Resilience
Security	Real-time collision reporting	Emergency response optimization	Disaster early warning
Mobility	GTFS feed provision	Fleet management systems	Bus service rerouting in the wake system disruptions
Water and Sanitation	Flood alert systems	Satellite leakage detection and control (to inform repairs to reduce water loss)	Satellite leakage detection and control (to inform efforts to improve the resilience of the infrastructure system to quakes and other hazards)

Unit of Analysis

The unit of analysis varies by the sector in which an application is adopted. Crime mapping, for example, is adopted by actors in the security sector, namely city- or county-level police agencies. Leak detection software, on the other hand, is adopted by different types of local water providers, including city government departments, special water districts, and private water companies. In California, the authors have identified 328 city police departments in the security sector. In the water sector, we have identified 365 city-level public agencies, 333 special districts, and 14 private entities that serve 2,000 connections or more. In the transit sector, they have identified 44 county agencies, 119 city agencies, and 42 special districts.

Pilot Study Data Collection: Identifying the Opportunities and Limitations of Webscraping

During this pilot phase, we assessed the circumstances under which data on technology adoption by local public agencies could be collected via webscraping, and when more labor-intensive methods would be required. Webscraping is an automated data collection technique to extract information from internet sources. For this report, we extracted publicly available information from the websites of local public agencies and private companies that supply them with smart technology services. For example, a company called Granicus is the primary entity that helps public agencies stream live videos of their planning meetings to enhance transparency. One can scrape this provider's website to identify which agencies it serves. Transit agencies, on the other hand, may provide links to the videos on their websites, which also can be scraped. Webscraping can be redone periodically to update the data. Please see Appendix B for discussion of how webscraping was performed for specific technologies.

To guide the data collection effort, for each service provider (i.e., local public agency) and technology application provider, we determined whether the application is "citizen-facing" or "internal."[4] A citizen-facing application is one that can be accessed by, or which affects the decision-making of, residents in an agency's jurisdiction. An internal application, in contrast, is one that is used within service providers to assist with operations. Some applications can have both citizen-facing and internal functions. We hypothesized that a webscraping strategy would be more effective for learning about the adoption of citizen-facing applications as service providers will have to publicize the locations in which an application is adopted to generate consumer usage. Measuring the adoption of internal applications, in contrast, would require either service provider surveys or, in the case of a technology provided by an external vendor, for the vendors to share lists of customers.

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[4] In this discussion, a utility, special district, or city that provides public services is referred to as a *service provider*, while a company providing smart-city technology either to a service provider or to citizens using these services is referred to as an *application provider*.

For both citizen-facing and internal applications, our methodology also identifies the level of market fragmentation of application providers. Certain technologies are built and sold by one main provider, whereas others are made available by many. For almost all technologies, agencies have the option of developing an application internally, often with the assistance of a consulting firm. Our methodology characterizes technology applications for which self-provision is common as fragmented. For applications that are currently evolving, such as real-time fleet management (based on cloud technology), the level of market fragmentation will likely change over time with application provider entries, exits, mergers, and acquisitions. These distinctions are important because the feasibility of webscraping decreases with market fragmentation, unless data on adoption is already being collected by a third-party source.[5] Contacting vendors, however, is also less feasible in more fragmented markets.

To test the feasibility of using web-scraping to collect data on technology adoption for citizen-facing technologies, we undertook a data collection pilot study. In this study, we scraped a combination of websites belonging to both technology adopters and technology providers for the twelve technologies listed in Table 5, from the water and sanitation, security, and mobility sectors.

Information was first collected on and whether an application is internal- or citizen-facing and on the degree of market fragmentation. The information for this table comes from interviews with industry experts and the authors' experiences with data collection.

Appendix B describes the applications and data collection strategies employed, as well as the extent to which the data collection proved straightforward or presented challenges. The twelve technologies are discussed in the following order: 1) those that are both internal and citizen-facing, 2) those that are primarily citizen-facing, and 3) those that are internally-facing. For each technology, next steps for data collection were formulated, including ways to overcome the identified challenges.

The next section provides an illustration of one technology specific to transit service operations called General Transit Feed Specification (GTFS).

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[5] For example, there is already existing data on the provision of general transit feed specifications (GTFS) by transit agencies. These public schedules of arrival and departure times are individually created by each agency. Nevertheless, several third-party entities, such as OpenMobility or Transitland, have consolidated the offerings into one source.

Table 5. Summary of data collection strategies for technology applications piloted and discussed in detail in Appendix B

Application	Internal or Citizen-facing?	Sector	Market Fragmentation	Data collection strategy
Transit signal priority	Both	Mobility	Fragmented. Up to 5 main external providers, but with a great deal of self-provision	Webscraping possible, but service-provider surveys most efficient
Gunshot detection	Both	Security	One provider	Webscraping straightforward
GTFS transit data	Citizen-facing	Mobility	Fragmented. All agencies self-provide, central repository for feeds provided by OpenMobility	Webscraping straightforward
Demand-based microtransit	Citizen-facing	Mobility	Up to 10 main providers	Webscraping straightforward
FEMA Public Safety Alerts	Citizen-facing	Security	One provider	Webscraping straightforward
Crime mapping	Citizen-facing	Security	Low degree of fragmentation. 3-5 main providers	Webscraping straightforward
Public safety notifications (opt-in)	Citizen-facing	Security	One main provider, some self-provision	Webscraping feasible; service provider surveys most effective for measuring self-provision
Live meeting videos	Citizen-facing	Water, Security, Mobility	One main provider, some self-provision	Webscraping feasible; service provider surveys most effective for measuring self-provision
Smart water metering	Citizen-facing	Water	Fragmented. A great deal of self-provision	Webscraping possible, but service-provider surveys most efficient
Real-time fleet management	Internal	Mobility	Extremely fragmented and evolving	Service provider surveys required
Satellite leak detection	Internal	Water	One provider	Customer lists private; service provider surveys seem most effective
Smart stormwater management	Internal	Water	Fragmented, with a great deal of self-provision	Service provider surveys required

Future Strategies for Data Collection

Building upon these insights regarding the circumstances under which webscraping is more and less effective as a means of collecting data on technology adoption, we developed a plan for comprehensive data collection that the current team or others can undertake in the future. This work is being funded through a follow-on grant from UC ITS SB 1 grant for the 2020-2021 academic year. As part of this effort, we will incorporate citizen-facing and internal technologies where market fragmentation is high, and where web-scraping is therefore a less effective means of obtaining information about technology adoption. For these types of technologies, we will conduct surveys of service and application providers. Here, we will partner with sector-based organizations and regional associations, such as the current SB-1 partner Joint Venture Silicon Valley, a leading organization bringing together the public and private sectors.

This will lay the groundwork for next steps that we intend to pursue in the future: a membership program in which participating cities, special districts, and utilities provide information about technology adoption on an on-going basis. Agencies will have incentives to participate in order to learn from one another, contribute to broader understandings and research about technologies, and be able to submit requests for data on technology adoption by other agencies. These requests will allow us to track current technologies from the pilot and update the list of technologies being tracked through a combination of agency data provision, webscraping, surveys and other strategies. This should help ensure that the list of technologies included in data collection efforts continues to reflect the priorities of California public agencies. These next steps emerged during discussions held during 2019-2020, which included representatives of the public, non-profit and private sectors.

Along with data on technology adoption, we have been collecting important information regarding agency characteristics they expect to be associated with adoption and that helps them understand the social equity implications of differential rates of adoption. We have, for example, collected information on ridership, the geographic area served, and rider demographics for transit agencies. This will allow users of our data to examine patterns of technology adoption for transit providers that are similar to one another. Other researchers also will be able to identify important predictors of technology adoption. For data collected to date, visit the project website at: <connectedgov.berkeley.edu>.

Illustrating the Utility of Webscraped Data with GTFS Feed Adoption

This section demonstrates how the data collected can be used to learn about predictors and patterns of technology adoption. We focus on General Transit Feed Specification (GTFS), an open-source data format through which public transportation agencies share information about routes and vehicle stop and station arrival times. Agencies can publish static transit schedules (GTFS-s), or even incorporate real-time information (GTFS-r) (Figure A1 shows examples of each type). A variety of trip-planning applications, including Google Maps and the Transit mobile app for iOS and Android, rely on GTFS feeds to incorporate public transit information. Through these widely-used applications, both types of GTFS feeds help can reduce the individual time costs of ridership and difficulties connecting between services operated by different transit agencies.

In April 2020, the California Integrated Travel Project conducted a Feasibility Study that called for the widespread adoption of GTFS-s and GTFS-r to make transit simpler for California residents.[6] When centralized applications such as Google Maps or the Transit map integrate GTFS data, commuters can easily plan multi-modal trips with numerous connections. As shown at the conclusion of this section, GTFS is also key to system resiliency as it can facilitate communication between agencies and riders during emergencies and major service modifications or outages, such as those experienced during the COVID-19 pandemic.

To date, there is little research on patterns of information sharing across transit agencies. This section examines the transit provider and ridership characteristics associated with the publication of GTFS feeds. In the analysis, GTFS publication is defined as the public sharing of data feeds that can be widely used by multiple actors, from public agencies to private sector app providers. Learning about these patterns should help reveal barriers to publication, and potentially facilitate widespread adoption of this important data-sharing policy by transit agencies.

Data

This study examined patterns of data publication across California transit agencies that reported to the National Transit Database (NTD) in 2018, the most recent period of publicly available data as of April 2020. The NTD contains all California agencies that receive funding from the Federal Transit Administration. The database excludes 16 other agencies that account for only one percent of ridership

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[6] The study can be found here: https://dot.ca.gov/cal-itp

in the state.[7] The analysis in this study further excludes all agencies that provide demand-responsive service only (e.g., taxis, vanpools, and specialized services for seniors or disabled citizens). The final dataset has 172 agencies. Definitions and descriptive statistics for all variables included in this study are reported below in Table 6.

Outcome Variables

The study looked at whether or not agencies in the database published publicly available static (GTFS-s) or real-time (GTFS-r) feeds during April 2020. Data on publication of GTFS-s feeds was obtained from OpenMobility Data (www.transitfeeds.com). Data on the publication of GTFS-r feeds was coordinated with the California Integrated Travel Project. While several agencies might share their information with certain entities (such as the Transit mobile app) through private agreements, this study focuses on publicly available transit data feeds that are widely disseminated and integrated into third party-applications like Google maps. Future work may consider public agencies sharing with private entities as well.

Independent Variables

The 2018 NTD also provided data that may help explain why certain agencies are more likely to share data information, including each agency's organization type, NTD reporting type, vehicles operated, service area size, and the population of the service area.

The NTD classifies agencies based on the type of reporting required of them: Full, Reduced and Rural. Agencies that are relatively small or based in rural areas do not have to make full reports to the NTD.[8] It also groups transit agencies by type: a) independent public agencies or authorities; b) city, county or local government units; c) other types, including universities, tribes, private corporations, and regional councils of government, of which the dataset only includes nine total agencies.

The analysis also included data on city level sales tax rates and income levels. City level sales tax data was collected from the California Department of Tax and Fee Administration for 2020. Data on the mean income level as reported in the 2010 US Census by zip code comes from the Population Studies Center at the University of Michigan. These city and zip code level variables were joined with NTD data based on the zip code and city of the agency's main offices. Future work will merge tax and income level data with the NTD data by using transit agency service boundaries and a weighted average of the corresponding city and zip code level data.

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[7] Find more information here: https://dot.ca.gov/-/media/dot-media/documents/cal-itp/calitp-feasibility-study-042420-a11y.pdf

[8] Agencies that either a) receive federal funding specifically designated for rural areas (section 5311 from the Federal Transit Administration) or b) operate 30 vehicles or less across all modes and types of service and do not operate fixed guideway (such as rail or Bus Rapid Transit) and/or high intensity busway service are classified as rural or reduced reporters to the NTD, respectively.

Table 6. Definitions and descriptive statistics for outcome and other variables

Variable	Definition	N for which available	Mean	Min	Max
Dependent Variables					
GTFS-s	Indicator for the availability of a public GTFS-s feed	172	0.540	0	1
GTFS-r	Indicator for the availability of a public GTFS-r feed	172	0.190	0	1
independent Variables					
Service Area	Service area square mileage	133	812.000	0.000	1,736.000
Service Area Population	Population of service area	129	561,932.000	3,801.000	8,595,119.000
Density	Service area divided by population	133	5,012.000	0.000	6,999.000
VOMS	Number of Vehicles Operated to meet requirements on the data of Maximum Service	172	93.000	0	3,458
Tax rate	City-level sales tax	167	8.600	7.200	10.000
Mean income	Mean income for the zip code in which the agency headquarters are located	156	72,042.00	4,521.00	233,520.00
Type: City, County or Local Government Unit or DOT (Department of Transportation)	Indicator for agency type: city, county or local government units	172	0.610	0	1
Type: Independent Public Agency/ Authority	1 if independent agencies/authorities, else 0	172	0.37	0	1
Type: Other	1 if metropolitan planning organizations, councils of government, private firm, tribal agency, or university-based agency, else 0	172	0.952	0	1
Reporter Type: Reduced	1 if operating under 30 vehicles or less across all modes and types of service and not operating fixed guideway and/or high intensity busway service, else 0	172	0.34	0	1
Reporter Type: Rural	1 if receiving federal funding specifically designated to rural areas (section 5311 from the Federal Transit Administration), else 0	172	0.23	0	1
Reporter Type: Full	All other agencies reporting to the National Transit Database	172	0.44	0	1

Analysis and Results

Of the 172 agencies in the dataset, 93 (54 percent) had published GTFS-s feeds. Only 32 agencies in California (19 percent) have published GTFS-r feeds. Figure A2 breaks down the study agencies by reporter type and agency type and whether they have published either static or real-time information.

Reduced and rural reporters are less likely than the larger full reporters to have published GTFS-s feeds.

demonstrates that these trends hold even when controlling for the other variables listed above using an Ordinary Least Squares (OLS) linear probability model. Model 1 includes all of the variables. Model 2 excludes variables that are collinear (or redundant) with the explanatory variable Reporter Type: Rural. “Other” type transportation agencies are also less likely than government run and independent public transit authorities to publish feeds, but this category of operator is small and has only nine members, making inference from this pattern difficult.

These trends also hold for GTFS-r publication (Table 8). Furthermore, while the majority of transit agencies in California are government run, independent public transit authorities are more likely to publish GTFS-r feeds than other types of agencies, particularly those operated by a county, city, or local government unit. Models 1 and 3 show that independent transit authorities are more likely to publish GTFS-r feeds than local government units. Models 1 and 2 indicate that rural and reduced reporters are less likely to publish GTFS-r feeds than full reporters. Model 4 further shows that even when the sample is restricted to only agencies that have GTFS-s or GTFS-r feeds, independent agencies are far more likely to publish real time (as opposed to simply static) feeds than other types.

In summary, we have identified two predictors of GTFS feed publication that operate independently of one another, namely 1) whether or not an agency is reasonably large and operates in an urban area, and 2) whether or not it is an independent public agency, as opposed to a department within a local government. These results suggest that larger agencies may have more resources to devote to publishing feeds or that independent agencies could possess more incentives or capacity to develop innovative technological applications to attract customers. Potential barriers to publication at smaller agencies might be insufficient budget or personnel to implement and develop the feeds.[9] As a result, state or federal level funding and coordinated planning at the state and regional levels may help incentivize and facilitate the timely publication and dissemination of this important information thereby providing a stronger foundation for increased transit information for passengers and public agencies alike.

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[9] GTFS-s static information, for example, might be used to determine whether neighborhoods with certain demographic characteristics are likely to receive service more (or less) frequently. Other examples of publicly-relevant analysis that might be conducted with GTFS-s data can be found in Fayyaz S, S. Kiavash, Xiaoyue Cathy Liu, and Guohui Zhang. "An efficient General Transit Feed Specification (GTFS) enabled algorithm for dynamic transit accessibility analysis." *PloS one* 12, no. 10 (2017): e0185333.

Table 7. Predictors of GTFS-s Adoption among CA Transit Agencies, 2020.

	Dependent variable: **GTFS-static feed publication**[1]	
	(1)	(2)
Type: Independent Public Agency or Authority of Transit Service	0.140	
	(0.120)	
Type: Other	-0.700**	
	(0.320)	
Service Area Population	0.00000	
	(0.00000)	
Service Area	0.0001	
	(0.0001)	
Tax rate	-0.065	-0.051
	(0.075)	(0.045)
Reporter Type: Reduced[3]	-0.360***	-0.490***
	(0.110)	(0.089)
Reporter Type: Rural		-0.270***
		(0.100)
Mean	0.00000	-0.00000
	(0.00000)	(0.00000)
Density	-0.00000	
	(0.00004)	
Constant	1.100**	1.200***
	(0.560)	(0.410)
Observations	111	151
R^2	0.370	0.200
Adjusted R^2	0.320	0.180
Residual Std. Error	0.410 (df = 102)	0.450 (df = 146)

p<0.1; **p<0.05*;***** p<0.01. All models estimated using ordinary least squares.

[1] *Standard errors corrected to be heteroskedasticity-robust (HC2).*

[2] *Reference category is* Type: City, County or Local Government Unit or DOT.

[3] *Reference category is Reporter Type: Full.*

Table 8. Predictors of GTFS-r Adoption by CA Transit Agencies, 2020.

	Dependent variable: GTFS-real time feed publication			
	(1)	(2)	(3)[4]	(4)[5]
Type: Independent Public Agency or Authority of Transit Service	0.260^{**}		0.280^{**}	0.360^{***}
	(0.100)		(0.140)	(0.140)
Type: Other	0.280		0.280	
	(0.290)		(0.370)	
Service Area Population	-0.00000		-0.00000	-0.00000
	(0.00000)		(0.00000)	(0.00000)
Service Area	-0.0002^{*}		-0.0002	-0.0002
	(0.0001)		(0.0001)	(0.0001)
VOMS			0.0001	0.0001
			(0.0002)	(0.0002)
Tax rate	-0.001	0.023	0.002	0.008
	(0.067)	(0.036)	(0.100)	(0.110)
Reporter Type: Reduced[3]	-0.230^{**}	-0.300^{***}		
	(0.095)	(0.072)		
Reporter Type: Rural		-0.160^{*}		
		(0.081)		
Mean	-0.00000	0.00000	-0.00000	-0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
Density	0.00002		0.00003	0.00005
	(0.00004)		(0.0001)	(0.0001)
Constant	0.190	0.078	0.130	-0.086
	(0.510)	(0.330)	(0.780)	(0.780)
Observations	111	151	67	60
R^2	0.210	0.110	0.110	0.160
Adjusted R^2	0.140	0.090	-0.012	0.051
Residual Std. Error	0.370 (df = 102)	0.370 (df = 146)	0.470 (df = 58)	0.450 (df = 52)

**p<0.1; **p<0.05;* ******* p<0.01. All models estimated using ordinary least squares.

[1] *Standard errors corrected to be heteroskedasticity-robust (HC2).*

[2] *Reference category is* Type: City, County or Local Government Unit or DOT.

[3] *Reference category is Reporter Type: Full.*

[4] *Model includes full reporters only.*

[5] Model includes only agencies with either GTFS-static or GTFS-realtime.

GTFS and Resiliency During COVID-19

As California's experience during the COVID-19 pandemic shows, the widespread adoption of GTFS-r is key facet of transit system resiliency. The introduction of shelter-in-place orders and social-distancing guidelines during the pandemic greatly reduced the use of public transit. Based on usage of the Maps app, Apple estimates that transit use in the United States decreased by 75 percent between January 13 and April 25, 2020.[10] Many public transit providers across the country cancelled or modified their services in response to this decline.

During the week of April 20, 2020, we studied efforts by 30 transit agencies across California to communicate service modifications to the public through websites and GTFS feeds (Table 9). We examined randomly selected samples of 10 agencies that did not publish any type of public GTFS feed, 10 that shared static information using GTFS-s, and 10 that shared real-time information using GTFS-r. Data on GTFS-s feed publication were webscraped from a centralized online repository, and data on GTFS-r feed publication coordinated with the California Integrated Travel project.[11] While several agencies share their information with certain entities (such as the Transit mobile app) through private agreements, the researchers defined GTFS publication as the public sharing of feeds that can be widely used by multiple actors, from public agencies to private sector app providers.

We found that service modifications were common during the pandemic. According to the websites of the 30 agencies studied, 23 had modified service schedules. They further found that use of GTFS-r was essential to the timely and accurate communication of service modifications and coordination of connecting trips between transit agencies. Of the 10 agencies using GTFS-r during normal operations, eight continued to use GTFS-r during the pandemic and were thus able to directly communicate service changes to riders in an automated and efficient fashion. In contrast, while eight of the 10 agencies using GTFS-s during normal operations made some type of service modification or cancellation, these changes were only reflected in the public GTFS-s displayed through Google Maps for three of the eight agencies.

The COVID-19 pandemic shows that the widespread adoption of GTFS-r in particular is essential to the resiliency of communities to emergencies. In situations where services are continuously modified, it is costly for agencies to constantly update their GTFS-s feeds, and this information is less likely to reach users than GTFS-r feeds integrated into applications like Google Map

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[10] Apple has made this data public beginning in January 13th. The data for this project was collected on April 25, 2020. Find more information here: https://www.apple.com/covid19/mobility

[11] The online repository scraped can be found at https://transitfeeds.com. Information in this background paper is current as of April 1, 2020.

Table 9. Summary of service modifications and incorporation of changes into Google Maps by transit agency

	Agency Name	City	Service modification	Modification incorporated into Google Maps
Agencies using GTFS-realtime	Alameda-Contra Costa Transit District	Oakland	Yes	Yes
	City of Lakewood	Lakewood	Yes	Yes
	City of Santa Monica	Santa Monica	Yes	Yes
	Golden Gate Bridge, Highway and Transportation District	San Francisco	Yes	Yes
	Lake Transit Authority	Lower Lake	Yes	Yes
	Long Beach Transit	Long Beach	Yes	Yes
	Marin County Transit	San Rafael	Yes	Yes
	Napa Valley Transportation Authority	Napa	Yes	No
	San Francisco Bay Area Rapid Transit District	Oakland	Yes	Yes
	Western Contra Costa Transit Authority	Pinole	Yes	No
Using GTFS-static	City of Corona	Corona	Yes	Yes
	City of Fairfield	Fairfield	Yes	Yes
	City of Petaluma	Petaluma	No	N/A
	County of Siskiyou	Yreka	Yes	No
	Gold Coast Transit	Oxnard	Yes	No
	Lassen Transit Service Agency	Susanville	No	N/A
	Mountain Area Regional Transit Authority	Big Bear Lake	Yes	No
	Plumas County Transportation Commission	Quincy	Yes	No
	Southern California Regional Rail Authority	Los Angeles	Yes	No
	Ventura County Transportation Commission	Ventura	Yes	Yes
Not publishing any type of GTFS feed	Antelope Valley Transit Authority	Lancaster	Yes	No
	City of Arvin	Arvin	Yes	No
	City of Corcoran	Corcoran	No	N/A
	City of Glendora	Glendora	No	N/A
	City of Moorpark	Moorpark	Yes	No
	City of Whittier	Whittier	No	N/A
	Union City	Union City	No	N/A
	Los Angeles County Department of Public Works - South Whittier	Alhambra	Yes	No
	Pomona Valley Transportation Authority	La Verne	No	N/A
	City of Wasco	Wasco	Yes	No

Expected Impact from this Study

This report details our approach to assembling a public-facing dataset on the adoption of smart city technology in California. The approach was developed to generate comprehensive information on 1) which types of technologies are being adopted; and 2) which California public agencies — varying in population, population density, geography (rural versus urban) and other characteristics — have adopted new technologies most frequently. Our research team completed data collection as possible for a sample of twelve critical applications through webscraping. The sample data collected information not only from the transportation sector but also technology adoption in the water and security sectors to compare patterns across sectors. As noted above, webscraping proved to be more effective for some technologies than others. The data collected to-date — which spans GTFS publication, live public meeting videos, crime-mapping tools, opt-in public safety alerts, FEMA public safety alerts, and gunshot detection — is publicly available at connectedgov.berkeley.edu.

As recommended in this report and as part of a follow up UC ITS grant for the 2020-2021 academic year, we plan to conduct interviews and surveys of the public and private sectors for a more comprehensive coverage of technologies and assess the potential for a membership model in which participating cities, special districts, and utilities provide information about technology adoption on an on-going basis in order to learn from one another and contribute to broader understanding and further research about technology adoption by other agencies in California.

In sum, the overall methodology outlined in this report can be used to develop a comprehensive and sustainable long-term data-collection strategy. Such a strategy will enable engineers, social scientists, policymakers and members of the public to learn about and develop rigorous evaluations of smart city technologies.

Across sectors and jurisdictions, it also will enhance the scope for communication by providing actors with better information about technology adoption *within* their own jurisdictions or sectors, particularly where there may not be extensive communications between infrastructure departments in an agency. Information sharing within agencies and more publicly may further promote the development of new technology or curtail its use based on further critical analysis. For example, within the energy sector, control theory, a subfield of mathematics used to manage continuously operating dynamic systems, is widely applied. Yet it may have many useful applications in a piped water system as well. Agencies may also seek to coordinate their critical infrastructure to manage disasters. These propositions are supported by research on policy diffusion in political science and public administration that find the ability of jurisdictions to learn from, compete with, and emulate one another to be key factors in the adoption and spread of new policies (see Marsh and Sharman, 2009).

Data collected following the approach outlined in this report will also allow researchers to identify technical, economic, and political predictors, barriers and risks to adopting new technologies. Identifying these predictors will allow social scientists to consider the extent to which the adoption of smart city technologies is following the logic suggested by research in the social sciences on policy and technology diffusion (Linos 2013; Rogers 2003), or if they are characterized by distinctive dynamics. It will also allow researchers in the field of urban studies to consider whether or not aggregate patterns of adoption are consistent with the insights of the largely case-study literature on the diffusion of smart city technologies, which tend to emphasize the strong leverage of technology providers over public sector agencies (e.g., Viitanen and Kingston 2014). Eventually, these research findings might allow policymakers to reach important goals. In April 2020, for example, the California Integrated Transit Project conducted a Feasibility Study that called for the widespread adoption of GTFS-s and GTFS-r to make transit simpler and more cost effective for California residents.[12] Here, we have used the collected data to conduct a multiple regression analysis to determine key predictors of the publication of GTFS feeds by transit agencies across the state, potentially pointing to important barriers to feed adoption.

Finally, data collected following the methodology presented here can provide key metrics not only for levels of technology adoption, but also allow policymakers and analysts to identify critical issues of social equity and justice, sustainability, and resiliency. For example, the analysis of the importance of GTFS-r during the COVID-19 pandemic shows that this technology is essential in facilitating public transit use during a time when a disproportionate number of low-income workers still had to report to work. More generally, certain smart city technologies can help ease burdens that disproportionately affect vulnerable populations. Other technologies, on the other hand, may generate significant privacy, security and other concerns. Analyzing this data in conjunction with community demographic information could also reveal whether certain communities are more likely to be subject to surveillance or vulnerable to privacy concerns due to the adoption of new technologies. Researchers and policymakers may further use the database as a starting point for projects that aim to measure whether the uptake of certain technologies is correlated with a range of outcomes, from social equity and justice to energy use. Analyses may then be disseminated and discussed in public and research venues, as well as in educational and workforce development settings.

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[12] The study can be found here: https://dot.ca.gov/cal-itp

Appendix A: Literature Review on Smart Cities and Technology Adoption

To further understand the circumstances under which smart city technologies are adopted by public agencies and other actors, this appendix reviews scholarship on the smart city concept and definitions in the academic literature as well as the adoption of innovations by policy actors. It further discusses how subsequent actors take up these innovations, known in the literature variously as innovation diffusion, policy transfer, policy diffusion, and policy mobilities.

Defining Smart Cities

Despite its ubiquitous use in the academic literature, professional and corporate discourses, and news outlets, the definition of a “smart city” is hotly debated. Most journal articles that discuss smart cities dedicate an initial section to reviewing definitional debates, as well as to establishing their own definition. The term “smart city” is generally used to describe the deployment of information and communication technologies (ICT) to improve urban services and infrastructure (e.g., Chourabi et al. 2012). However, some of the most cited definitions of a smart city (e.g., Caragliu et al. 2011; Giffinger et al. 2010) extend beyond ICT infrastructure to include factors such as human capital and education as key components. Caragliu and coauthors, for example, claim that smart cities not only use networked infrastructure to improve efficiency and enable social, cultural, and urban development, but are also characterized by their attention to high-tech and creative industries, to social and environmental sustainability, and to business-led development (Caragliu et al. 2011, 67–68).

At the root of these definitions and conceptions is a conflation of descriptive and normative perspectives of what constitutes a smart city. One line of research emphasizes the adoption of specific technology — sensors, Internet of Things (IoT), big data, e-services, high-tech facilities — as a way to characterize smart cities. Another literature, however, takes a normative stance that specifies the positive outcomes enabled by the use of these technologies — efficiency, sustainability, well-being of the population. Thus, “smart city” refers not only to the apolitical use of technology in the urban context, but also to the assumption that an ideal city can be achieved through technology. As Meijer and Rodríguez Bolívar (2016) argue, most definitions conflate what smart cities *are* with what they can *achieve*. There is no consensus, however, regarding what constitutes an “ideal city.” This has led to a polarization in the literature on smart cities between optimist and critical perspectives. Literature that has an optimistic stance often highlight the potential of new technologies to generate improvements in the city — increased efficiency in service delivery, more sustainability, more capacity to react on time, and increased public engagement. Alternatively, the critical literature highlights what is left out of this view — reduction of spatial inequalities, environmental justice, and risks to increased public surveillance and over policing, and contrary to the optimists, citizen engagement — claiming the adoption of technology often serves private corporate interests over the common good.

Definitions of a “smart city” and its goals are constantly being reshaped, often as a result of particular critiques in the literature. Notably, much recent research incorporates “participation” as a normative focus of the smart city, alongside efficiency gains in service provision. This shift represents a reaction to critiques from the late 2000s, in which authors argued that promoters of smart cities had an underlying agenda of using public resources to attract mobile global capital; smart city projects therefore, were geared more towards corporate than citizens interests (e.g., Hollands 2008). Scholars within the same critical literature made the case for a more “progressive smart city” (ibid., 315), trying to reorient the concept towards policies that focused more on people, human capital, and citizens’ needs. Following this call, different authors pointed to the potential of smart cities to expand public engagement in policy-making through technology (e.g., Deakin 2014; Viitanen and Kingston 2014). This prompted shifts in corporate and government discourse; promoters started to present smart city solutions also as a way to increase citizen involvement in governance. Participation and citizen engagement soon became commonplace in definitions of smart cities. Recent critical scholarship, however, has noted shortcomings in these efforts to facilitate participation through technology, arguing that citizens are now treated as data points (Gabrys 2014) or consumers in a marketplace of services (Cardullo and Kitchin 2018), rather than actual participants in policy-making.

Another strand of critique comes from scholars focusing on issues of inequality and justice. This line of research suggests that smart city initiatives deepen social divisions in cities. This argument appeared in early, broader debates about the diffusion of information and communication technologies that created clusters of super-connected people and firms, while leaving behind a significant portion of the urban population with poor access to these technologies (Graham 2002). Some authors stress the importance of the work done by smart cities as a representation of an ideal, claiming that the mobilization of a “smart” future serves the purpose of justifying projects that are ultimately exclusionary and reinforce unequal power dynamics (Jazeel 2015, Moser 2015). Others assert that smart city projects and discourses sideline major social issues and divert resources that could go to projects responding to more pressing demands from marginalized communities (Hollands 2008). Still others articulate this critique in terms of environmental justice, claiming smart city technologies might increase the gap between poorer and wealthier communities in terms of exposure to environmental risks, since they “tend to cluster around locations with high gross value added,” which “leads us to question the prospects of smart cities offering social and environmental progress (Viitanen and Kingston 2014, 814).”

Scholars also argue that smart city initiatives establish new modes of disciplining, surveilling, and controlling city residents (Vanolo 2014, Krivý 2018). In particular, Krivý argues that smart city policies facilitate governmental control of the population from a distance, creating a “society of control.” Others further state that algorithmic-based data driven processes lead to: 1) digital “municipal redlining” akin to historical redlining in the United States that exclude some areas within a city when localities consider investments of public services and infrastructure (Safransky 2019), or 2) other harmful impacts to marginalized and racialized residents, including on the basis of gender, such as increased surveillance, over policing, and discrimination in hiring or access to health care, also referred to as *algorithmic bias* (Benjamin 2019, Jefferson 2018, Noble 2018).

Relevant Perspectives on Technology and Policy Diffusion

How can one understand variation in the adoption of smart city technologies? Why do patterns vary across particular technologies, and across different types of public and private sector actors? It is unclear whether patterns observed with respect to smart city technologies will differ from those observed with other types of innovations and technologies. This report now summarizes key theoretical perspectives on technology and policy adoption that may help us understand the diffusion of different types of smart city technologies.

The literature on the diffusion of innovations provides a useful lens for understanding patterns of technology adoption. Scholarship by sociologist and communications scholar E.M. Rogers (2003) over the last four decades details the key actors involved with innovation and technology adoption and diffusion; "adoption" refers to the moment when one actor takes up an innovation, while "diffusion" occurs when additional actors adopt such innovation. According to Rogers, "[core diffusion components] of new ideas are: (1) *an innovation*, (2) which is communicated through certain *channels*, (3) *over time*, (4) among the members of a *social system*" (Ibid, 35, *emphasis in original*). The decision to adopt an innovation may take the form of a *collective innovation-decision* with consensus among those involved within a system, an *optional innovation-decision* with individual adoption independent of decision of others within a system, and an *authority innovation-decision* made by a small group of actors in powerful positions or with technical expertise such as senior/corporate management (Ibid, 370).

New innovations can create much uncertainty in their consequences and thus actors seek information about an innovation's strengths and weaknesses (Ibid, 28). Rogers identifies five central characteristics of an innovation that influence adoption, some which are related to issues of uncertainty: 1) *complexity*, i.e. how difficult it is for adopters to learn how to use it; 2) *trialability*, i.e. how easy potential adopters can give it a test run before adoption and the extent to which it can be parsed into smaller, testable components; 3) *observability*, i.e. to what extent positive results are easily perceived by adopters; 4) *relative advantage*, i.e. how improved an innovation is compared to the previous technology (for example, if it offers better service, more efficiency etc.); and 5) *compatibility*, i.e. to what extent the new innovation is compatible or easy to assimilate into existing lifestyles and structures (Ibid, 48).

Rogers also develops a typology of adopters and designated percentages to each category based on a modified normal bell curve distribution (refer to Figure A1). *Innovators* are the first to adopt, "venturesome" and able to withstand much uncertainty and even some failure. *Early adopters* are considered visionary, highly regarded among their peers, and conduct much evaluation of an innovation and careful attendant adoption. Once they adopt said innovation and provide their respected endorsement, others follow in adoption in the form of the *early majority* who are more "deliberate" and take more time than the latter two types, but prefer not to be the last to adopt. The *late majority* may have been skeptical of the innovation, lack financial resources, or have other challenges or concerns. Finally, late adopters, which Rogers termed "*laggards*", are the last to adopt in part due to the fact that they possess significant skepticism or caution, lack awareness about the innovation, face other impediments, or are otherwise reticent (Ibid, 260–264).

The time dimension also plays a role in the cumulative adoption of innovations as knowledge spreads between existing and potential adopters. Often for highly diffused innovations, adoption grows in an upward sloping curve that resembles the letter "s" and referred to as an "S curve." Initially only a few adopters (the innovators to early adopters) innovate; then, the adoption curve sharply inclines with innovation uptake by the early majority and late majority and then peaks and flattens out with late adopters' ("laggards") innovation adoption (Ibid, 35, 260–264).

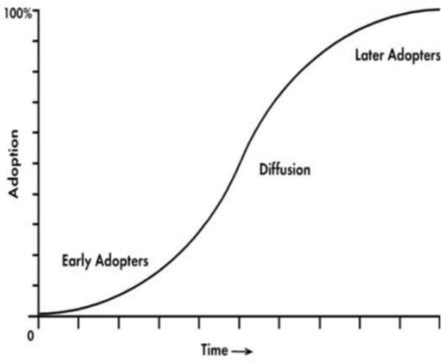

Figure A1. Technology Diffusion Curve with Adopters by Ideal Type (Rogers 1995).

In parallel research, a social science literature examining policy adoption and diffusion — variously termed as "policy transfer," "policy diffusion," or "policy mobilities" — has developed in recent decades. In a frequently quoted definition, policy transfer is understood as the process by which "knowledge about policies, administrative arrangements, institutions and ideas in one political setting (past or present) is used in development of policies, administrative arrangements, institutions and ideas in another political setting" (Dolowitz and Marsh 2000, 5). For Marsh and Sharman (2009), the "policy transfer" literature is typically concerned with public policy and emphasizes more qualitative analysis, with a limited number of case studies. The "policy mobilities" literature similarly focuses on how policies travel from one context to another, but with a particular concern on the potential negative influence of private actors, such as international consultancy firms and technology and other corporations, on public policy and planning processes in the interest of private gain over the social good (e.g., McCann, 2011; McCann and Ward, 2013). Throughout this literature, the primary emphasis is explaining variation across jurisdictions or government bodies in whether or not adoption occurs, the timing of adoption, and the extent to which policies are modified or transformed during the adoption process. The geographic units of analysis vary, ranging from city-to-city policy transfer (e.g., sustainable transportation policies in Marsden et al. 2011) to diffusion among nation states (e.g., economic, health, education policies).

Marsh and Sharman (2009) identify four theoretical mechanisms that have been used in the "policy transfer" literature to explain both policy diffusion and transfer between actors. First, there's a *learning* scenario, when governments decide to emulate an institution or practice from elsewhere. Second, *competition* refers to cities or countries adopting broadly similar investor-friendly policies (e.g., privatization, deregulation) to attract global mobile capital. The third mechanism is *coercion*, which refers to impositions from powerful states or international organizations (e.g., World Bank) through, for example, attaching conditions to their loans to coerce government action — of note here, little scholarship has uncovered coercion as a key factor in policy adoption (Marsh and Sharman 2009, 272). And, finally, the fourth mechanism is *mimicry*, that is, the process of copying policies from other countries or subunits (e.g., those perceived as more advanced or progressive) for their symbolic or normative factors, for the purposes of gaining legitimacy, rather than technical or other concerns.

Other scholars identify some variation in these “policy transfer” mechanisms. For example, Berry and Berry (2007) propose a model that includes *citizen pressure*; Linos (2013) recently made a similar argument, claiming diffusion also happens when domestic constituents impact policy choice through electoral dynamics, which she identifies as a *democratic mechanism*. However, very little work to-date has examined the extent to which these theoretical perspectives offer analytic leverage in explaining variation in the adoption of smart city technologies across jurisdictions (for exceptions, refer to Crivello 2015 and Wiig 2015).

Summing up

As outlined above, there is a vast literature that considers smart cities and policy diffusion that spans computer science, engineering, and the social sciences. Overall, this review finds the definition of a “smart city” to be the subject of a substantial debate, often normatively charged in both positive and negative directions and with varying levels of consideration in underlying historical situations, social structures and conditions, and structural inequities and outcomes.

The authors further described several literatures that may offer insights into the determinants of smart city technology adoption. The literature in technology diffusion, as well as scholarship on policy transfer, diffusion, and mobilities within the social sciences and urban studies offers theoretical perspectives on how policies and technologies adopted in one jurisdiction become implemented in other jurisdictions. These perspectives will be useful for those who will analyze the data on smart city technology adoption collected through this project. They will suggest hypotheses regarding the community and jurisdiction characteristics that may be most strongly associated with technology adoption, as well as theoretical intuitions regarding the types of smart city technologies that may diffuse most rapidly or extensively.

Appendix B: Summary of Technology Applications and Data Collection Efforts

This appendix describes the applications and data collection strategies employed for the twelve technologies piloted (as listed in Table 5), as well as the extent to which the data collection was straightforward or presented challenges. technologies are discussed in the following order: 1) those that are both internal and citizen-facing, 2) primarily citizen-facing, and 3) only internal. For each technology, next steps for data collection also are also provided including ways to overcome the identified challenges.

Relevant for both citizen-facing and internal operations

Transit Signal Priority

Fragmented; data collection incomplete

A transit signal priority system reduces the travel time for mass-transit vehicles, mainly buses, by either shortening red lights or holding green lights. There are a few independent private providers of this technology, several cities and transit agencies have developed this capacity in-house. The capacity is frequently featured on transit agency websites.

Next steps for data collection: Website scrape or service provider survey

Gunshot detection

One provider; data collection complete through website scrape

Shotspotter is the main vendor for gunshot detection technology.[13] A full list of cities in which the technology is deployed is available at https://www.shotspotter.com/cities/. Currently, **13 out of 328** cities in California have deployed this technology.

Next steps for data collection: Periodic website monitoring

Citizen-facing applications

GTFS Feeds

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[13] SafeZone is an alternative provider that sells detection units to individuals, rather than police departments. The authors focus on adoption by police departments.

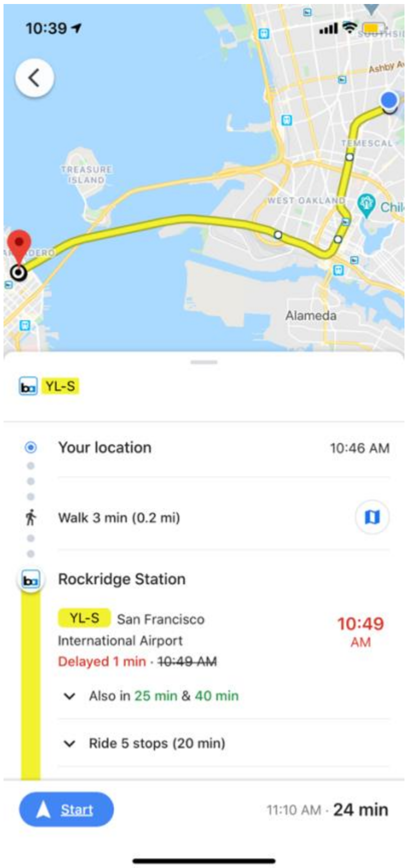
Fragmented provision with centralized data compilation; data collection complete, with scope for more comprehensive data collection

A General Transit Feed Specification (GTFS) is a format used by transit agencies for communicating their arrival and departure time information to passengers throughout the route (Figure A2). Agencies can provide either static information about arrival or departure times, or they can generate realtime information (called GTFS realtime or GTFS-r). These feeds are in an open-source format and can be used by anyone to develop applications that either use or present data to consumers.

We first measured whether or not transit agencies publish publicly available GTFS and GTFS-r feeds. This was challenging because there is no central repository for these feeds. OpenMobilityData (www.transitfeeds.org), however, attempts to maintain an up-to-date database of all of the feeds. We confirmed that this list is comprehensive by comparing its information with that found on the websites of **15** transit providers of varying size and geographic location. Data on GTFS-s were comprehensive, but data on GTFS-r were not. The authors coordinated with the California Integrated Travel project to obtain data on GTFS-r publication. A potential next step is to compare these lists to those published by TransitLand (www.transitland.com).

GTFS-s (static) feeds are widely published, but the prevalence of GTFS-r (real-time) feeds remains low. Of the 209 units in the dataset, 91 (43.5%) had published GTFS-s feeds. Only 33 agencies in California (16%) had published GTFS-r feeds.

Next steps for data collection: Periodic website monitoring of OpenMobilityData, measuring GTFS-s and GTFS-r incorporation into Google Maps and Transit App, and comparing lists from OpenMobilityData to those published by TransitLand (www.transitland.com)



YL-S

Your location 10:46 AM

Walk 3 min (0.2 mi)

Rockridge Station

YL-S San Francisco International Airport 10:49 AM

Delayed 1 min · ~~10:49 AM~~

Also in 25 min & 40 min

Ride 5 stops (20 min)

11:10 AM · 24 min

Figure A2. The Google Maps app provides GTFS schedule and real-time data for BART.

On-Demand Microtransit

Moderately fragmented provision; data collection complete

Recent years have marked the growth of several types of on-demand microtransit — bikes and scooters that users can rent to make short trips. They are particularly useful for the “last mile” of a commute not covered by transit. Because they do not operate on any schedule other than a user’s needs, they can be categorized as an “on demand” service.

This is an industry with several providers. We collected a list of the major providers (as of January 2020) by consulting newspaper articles for 10 cities of different sizes across the state.[14] We found that the major providers in California were Lyft, Jump, Wheels, Bird, Bold, Lime, Scoot, and Spin.

We collected data on service areas from these providers’ websites. While there are many players in this market, they serve only a few major cities each, with the Bird serving the most cities, eight. In general,

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[14] The authors did a search on Google News for the city names and “scooter” or “bike” and collected information from all relevant articles.

the cities served most often are those in the Bay Area (including five East and South Bay cities), the greater Los Angeles Area (including other cities in the Los Angeles area), San Diego, and Sacramento.

Next steps for data collection: This is a rapidly evolving mobility area, and it will be important to monitor the expansion or dissolution of each of these companies. It is likely that new players will enter over time as well.

Federal Emergency Management Agency (FEMA) Public Safety Alerts

One provider; data collection complete

In contrast to the notifications that are sent only to those who opt in, an alert made through the Federal Emergency Management Agency (FEMA) Integrated Public Alert & Warning System (IPAWS) is sent to as many people as possible, through a variety of sources. Participating agencies can send messages of up to 360 characters within a fixed geographic area (accurate to one tenth of a mile) to be disseminated by radio, television, and wireless phones. A common example of a notification issued through the IPAWS system is an AMBER alert issued for a missing child.

Because citizens do not opt into these alerts, program participation is restricted and carefully regulated. Only federal, state, local, or tribal government agencies may participate. If a non-eligible actor needs to issue a notification, as in the case of Pacific Gas & Electric (PG&E) in the Bay Area reporting a fire near a transformer, it must work with the relevant local public agency to do so.

Eligible agencies must also go through a process to be able to issue notifications. They must complete training, select IPAWS compatible software to use, apply for a Memorandum of Agreement with FEMA, and then apply for public alerting permissions.

A list of all registered authorities is available at https://www.fema.gov/alerting-authorities. We scraped this list and found that **49 of 328** California cities currently have alerting authority.

Next steps for data collection: Periodic website monitoring

Crime mapping

Low degree of fragmentation; data collection complete

Crime-mapping refers to the display of geo-located crime data to citizens by police departments (Figure A3). Police departments generally do not have proprietary software for this service, but rather contract the data sharing service out to a provider. There are three major providers: CommunityCrimeMap.com, CrimeMapping.com, and SpotCrime.com. The authors were able to draw directly from each of these websites and automated a search for the jurisdictions in California. They found that **244 of 328** police departments use at least one of these tools.

Next steps for data collection: Periodic website monitoring

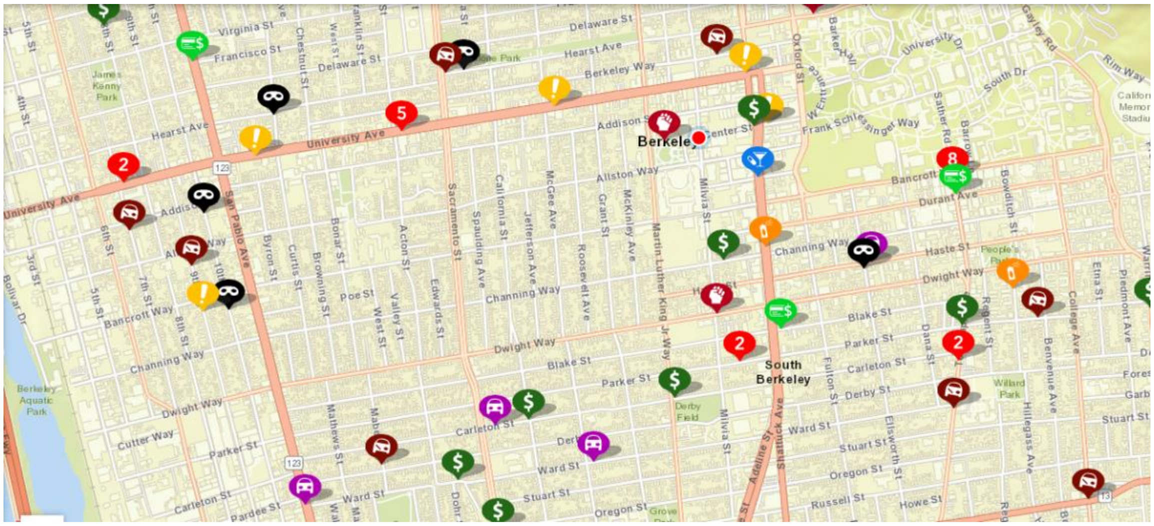


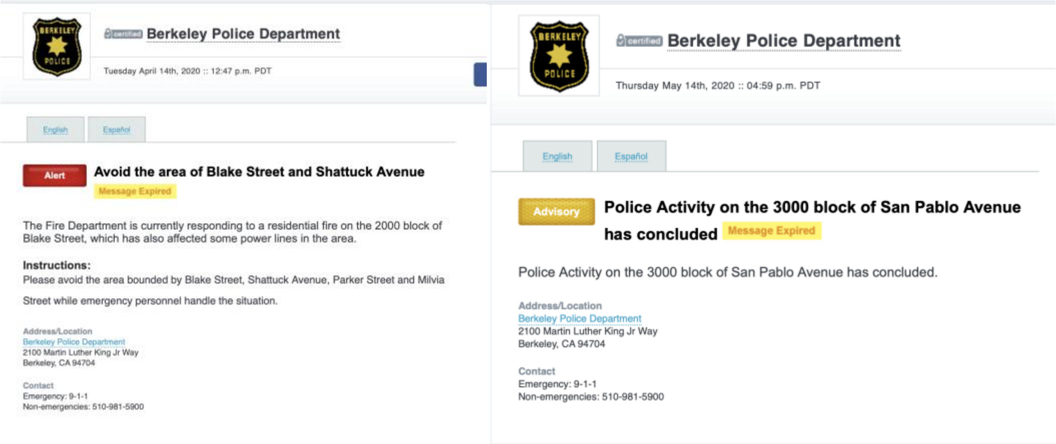
Figure A3. Screenshot of mapped crimes in Berkeley as seen in CrimeMapping.com

Public Safety Notifications (opt in)

One main provider; data collection complete

Service providers may want to send a variety of types of public safety alerts over phone or email to citizens who opt into the service (Figure A4).

Nixle is a platform used by public agencies to send safety notifications to all citizens who opt in. It is possible to conduct a search for any agency at https://local.nixle.com/agency_search/. For this project phase, we restricted the search to city-level police departments as this level of government tends to have greater responsibility for citizens' immediate security and safety within city limits. This entailed automating a search of each of the city-level police departments in California and collecting the number of notifications they had issued over a one-year period, from February 2019 to February 2020.



Berkeley Police Department

Tuesday April 14th, 2020 :: 12:47 p.m. PDT

Alert **Avoid the area of Blake Street and Shattuck Avenue**

Message Expired

The Fire Department is currently responding to a residential fire on the 2000 block of Blake Street, which has also affected some power lines in the area.

Instructions:
Please avoid the area bounded by Blake Street, Shattuck Avenue, Parker Street and Milvia Street while emergency personnel handle the situation.

Address/Location
Berkeley Police Department
2100 Martin Luther King Jr Way
Berkeley, CA 94704

Contact
Emergency: 9-1-1
Non-emergencies: 510-981-5900

Berkeley Police Department

Thursday May 14th, 2020 :: 04:59 p.m. PDT

Advisory **Police Activity on the 3000 block of San Pablo Avenue has concluded** Message Expired

Police Activity on the 3000 block of San Pablo Avenue has concluded.

Address/Location
Berkeley Police Department
2100 Martin Luther King Jr Way
Berkeley, CA 94704

Contact
Emergency: 9-1-1
Non-emergencies: 510-981-5900

Figure A4. Examples of Nixle alerts issued by the Berkeley Police Department.

Not all agencies participate, and even those that have accounts do not always issue notifications with any degree of frequency. Figure A5, for example, shows the distribution of citizen-facing notifications issued by police departments through the Nixle application across a one-year time period. As the histogram shows, most departments issue fewer than 10 notifications per year.

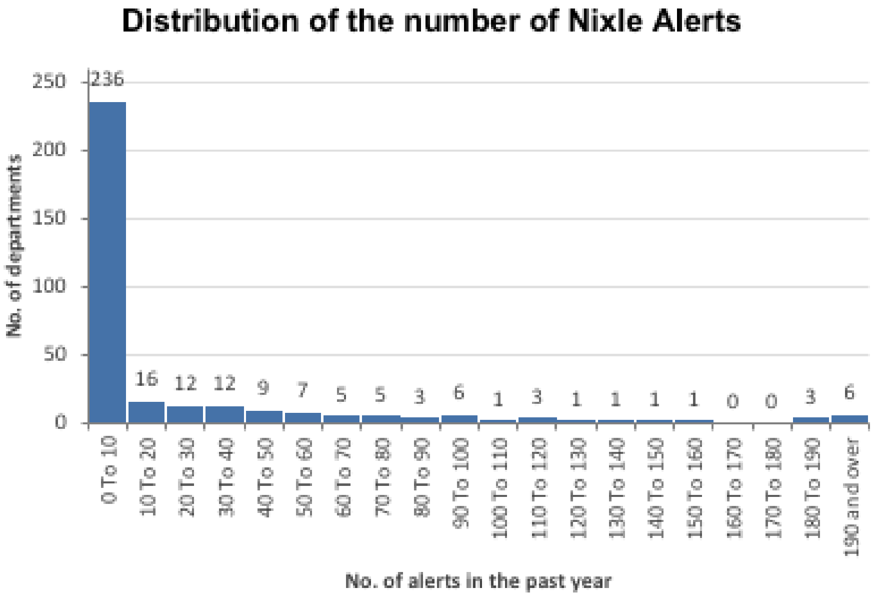


Figure A5. Distribution of the number of the total number of alerts (all types) made through Nixle by police departments in California from February 2019-February 2020.

Additionally, not all notifications are about public safety. An agency may tag a notification as "Community," "Advisory," or "Alert." A "community" notice might refer to low-priority notifications such upcoming events, or provide news on the successful location of a missing person. "Advisory" messages are slightly higher priority, and provide helpful information such as notifications of road closures or health concerns. "Alert" notifications are of the highest priority, and provide information about criminal activity, disasters, or missing children.

To summarize usage of Nixle, we developed the following binary rule: a public agency is recorded as a participant if it has issued 10 or more notifications in either the "Alert" or "Advisory" category in the past 10 years. This rule was developed to capture active and consistent usage of Nixle to send important security-related information to citizens. We find that **80 of 328** city-level police departments are using Nixle when defined in this way.

Next steps for data collection: Periodic website monitoring, and exploring other technology providers (see below)

Other providers

Agencies not using Nixle may use other small-scale providers, or develop their own crime alert system. Sacramento, for example, uses a proprietary crime alert system that can be found at http://www.crimealert.org/.

Next steps for data collection: *Automated search of agency websites.*

Live meeting videos

One main provider; data collection complete

Cities, special districts, transit agencies and private service providers may choose to make public meeting minutes and memoranda and attachments/powerpoint presentations, recorded videos, and even live and archived videos of meetings publicly available.

A major service provider to host these agendas and videos is Granicus (http://granicus.com). Granicus hosts a platform for upcoming agendas and video feeds. It also creates a searchable archive of past meetings (Figure A6). The platform may be embedded directly into a city's website.

We collected data on usage of this technology by exploiting Granicus's pattern of URL designation for city platforms, where the URL is designated as [cityname].granicus.com. We looped through the city names in the list and searched for the existence of webpages featuring some version of these names. The search revealed that **169 of 328** agencies have an account with Granicus. We further conducted this search with the transit units and found that **11 of 209** units use Granicus.

Next steps for data collection: A search of city Granicus pages to see whether or not they have dedicated sections for their police, transit, and water departments. It will also be useful to search for other service providers (below).

City Council Meetings

Meetings are arranged by date, with the most recent at the top of the list. Click **Video** to listen to the meeting and view agenda documents, or **Agenda** or **Minutes** to see just the documents. You can also search the archives by typing keywords into the Search box.

Streaming Video Help

Upcoming Events

Name	Date	Agenda	Event
City Council - April 8, 2020- Regular Meeting - CANCELLED	Apr 8, 2020 - 7:00 PM	Agenda	
Regular Planning Commission Meeting	Apr 15, 2020 - 7:00 PM		

Available Archives

Name	Date	Duration	Agenda	Video	MP3
EMERGENCY CITY COUNCIL MEETING - MARCH 12, 2020	Mar 12, 2020 - 5:33 PM	00h 14m	Agenda	Video	MP3 Audio
New Event TEST	Mar 11, 2020 - 2:42 PM	00h 09m		Video	MP3 Audio
City Council - March 11, 2020- Regular Meeting - Closed Session	Mar 11, 2020 - 5:30 PM	00h 02m	Agenda	Video	MP3 Audio

Figure A6. San Bernardino's Granicus platform.

Other providers

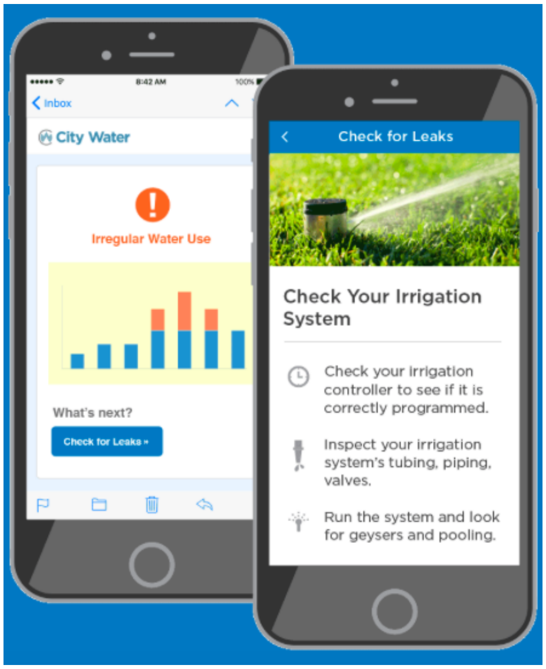
As an alternative to Granicus, a jurisdiction may host videos and information on its own website (using video platforms such as YouTube and Vimeo), through a solution created by a private consultant, or in partnership with a local news/television agency. The City of Bakersfield, for example, works with Kern Government Television to record and host videos of live and past meetings.

Next steps for data collection: To learn about whether jurisdictions are using this alternative solution, it is possible to scrape the websites of either service or technology providers.

Smart Water Metering Platforms

Fragmented provision; data collection incomplete

This citizen-facing innovation allows households to use a mobile or web-based platform to monitor their water use. Platforms can provide tips to decrease water use and alerts about potential leaks. Some platforms also provide billing and communications abilities.



Check Your Irrigation System

Check your irrigation controller to see if it is correctly programmed.

Inspect your irrigation system's tubing, piping, valves.

Run the system and look for geysers and pooling.

Figure A7. WaterSmart is an example of a citizen-facing smart metering platform.

Water providers can work with external companies, such as WaterSmart (Figure A7). They can also develop their own platforms, such as those used by Lakewood Water District, Foster City, and Davis. Further, there are a number of direct-to-consumer solutions that allow users to install sensors in their pipes and monitor their water usage. Some water providers, such as the East Bay Municipal Utility District, provide rebates to customers who install these sensors.

While there are a number of possible providers for these services, it is possible to scrape water provider websites for the presence of water use portals and rebates. This is mainly because this application is citizen-facing, so a company is likely to want to advertise any portals or rebates. Initial research entailed interviews with industry experts.

Next steps for data collection: Surveys of service providers (water agencies) or scraping of water provider websites.

Internal applications

Real-time Fleet Management

Fragmented; requires surveys

Transit agencies must use some type of fleet management system for many functions, including tracking vehicle locations, developing efficient routes and schedules, planning for service outages, vehicle maintenance, ensuring driver safety, counting passengers, logging incidents, and calculating future vehicle needs.

Adoption of real-time fleet management software could be tracked. In the past, much data was stored about vehicles and downloaded and analyzed only when buses pulled into a garage. In recent years, the development of 4G and 5G networks have allowed data to be transmitted to the cloud where it can be stored, processed and accessed in real-time.

There is currently a range of private providers for each of the real-time components of a fleet management system. This industry is changing rapidly, with mergers and acquisitions ongoing as of early 2020. Many transit agencies have also developed some of these functionalities in-house. For these reasons, learning about adoption through customer lists does not seem viable here.

Furthermore, as this application is not customer-facing, transit agencies are unlikely to provide data on technology adoption on their websites.

Next steps for data collection: Surveys of service providers (transit agencies).

Satellite Leak Detection

One provider; adoption private and measurement requires surveys

In the water sector, traditional acoustic leak detection programs can require teams to traverse an entire water supply network to find leaks, or sources of non-revenue water. A company called Utilis (https://utiliscorp.com) reduces the costs associated with this by using satellite images to help water providers detect where in the network they might be experiencing a leak. The system is based on one used to detect groundwater on the planet Mars.

While we have confirmed from informational interviews that water providers in California are using Utilis's technology, the company does not share its customer list.

Next steps for data collection: Surveys of service providers (water agencies).

Smart storm water management

Fragmented provision; requires surveys

Storm water management systems can use real-time data from weather forecasts or other sources to manage reservoir water levels. If a weather forecast predicts several inches of rain, for example, an actuated valve can release some of the water from a reservoir into a storm drain to prevent overflow (Figure A8).

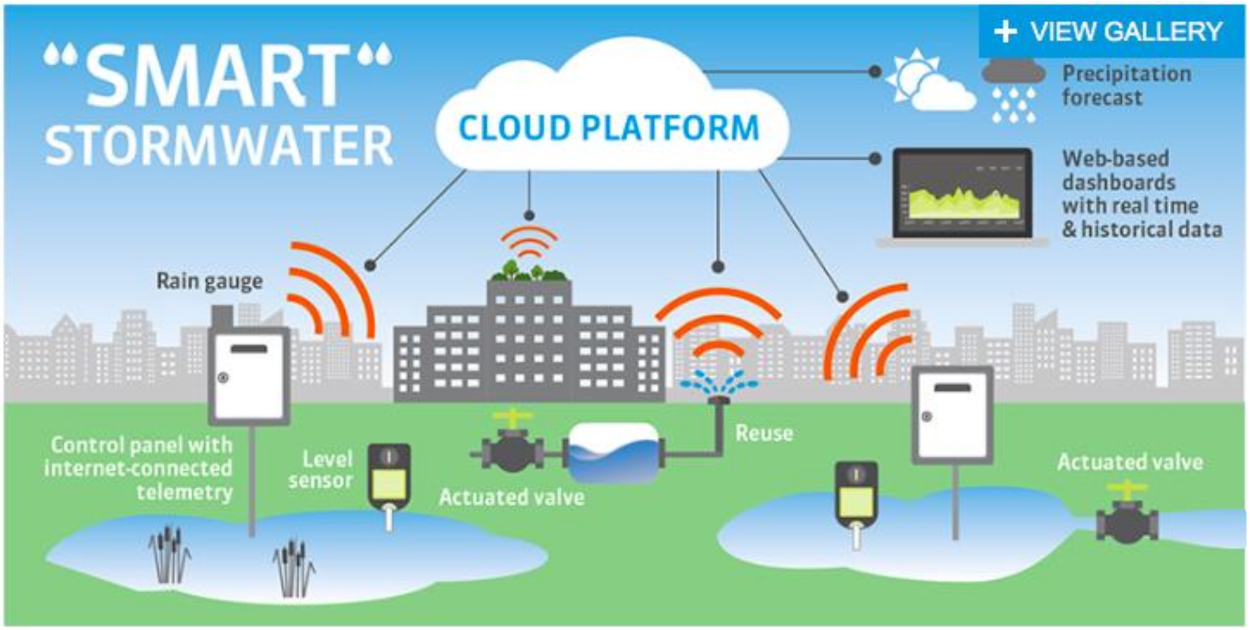


Figure A8. A concept map of real-time stormwater management created by Atkins, a design, engineering, and product management consultancy.

While we know of only one independent private provider for this technology (https://optirtc.com), several water service providers have developed this capacity in-house while working with consultancies. As this application is not customer-facing, providers are unlikely to have data on technology adoption on their websites.

Next steps for data collection: Surveys of service providers (water agencies).

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