Smart Cities and Transportation: Lessons from A Comparative Case Study of Singapore and Chicago

Abstract
As the smartness of cities becomes a major factor of their global competitiveness and the Communication and Information Technologies become an integrated component of transportation management, it is important to understand whether the Smart Cities initiatives are actually improving Quality of Life and promoting sustainable economic growth. To answer this question, initiatives and programs of Singapore and Chicago are examined and their effects are analyzed in terms of three common aspects of the Smart Mobility vision: quality of commute, sustainability challenges, and social challenges. Effective implementations are demonstrated through Singapore's Electronic Road Pricing system and Chicago's Divvy bikeshare program, and challenges are identified in Singapore's system and Chicago's speed camera program and 311 service platform. Finally, the comparative case study result stresses on the importance of public-private partnership, establishment of educational programs, and governmental adaptations to social-driven smartness for creating successful Smart Cities.

Keywords
Smart Cities; Transportation; Policy; Singapore; Chicago; Social Equity; Sustainability; Quality of Life

Introduction
Leveraging civic data enabled by Information and Communications Technologies (ICTs), more and more cities adopt Smart Cities initiatives to not only improve people's Quality of Life but also resolve urban challenges. Correspondingly, cities have the option to implement Smart Mobility initiatives which strive to enhance different aspects of transportation through incorporating innovative technologies. For example, some popular approaches include ride-sharing, road pricing, and safety surveillance. With Smart Mobility being a huge part of the Smart Cities ideology, its governance and its relationship to global competitiveness and sustainability have been studied and commended. However, smart transportation initiatives and technologies are not omnipotent. In order to plan for the right version of Smart Mobility, decision-makers ought to understand to what extent could smart initiatives resolve existing problems and potentially lead to new challenges. To study the impact of Smart Mobility implementation, this comparative case study examines the Smart Mobility implementation in two cities - the renowned Smart City, Singapore, as well as the aspiring Smart City, Chicago.

Literature Review

Smart Cities Initiatives

The concept of Smart Cities has emerged from the long-standing imagination of the perfect urban technological utopias (Glasmeier & Christopherson, 2015). When thinking about Smart Cities, people picture an urban environment where advanced technologies infiltrate every aspect of life, from transportation to governance. The base definition, as Voda and Radu (2018) summarize, refers Smart Cities as a system with ubiquitous and/or integrated technological infrastructure, which provides citizens real-time access to quality services and products.

With ICTs being the cornerstone of the Smart Cities concept, people have largely envisioned two scenarios of its application over the past 20 years. The perspectives bifurcate, in Rob Kitchin's opinion, with one focusing on using new, advanced technologies as an anchor for economic development, while the other emphasizing on applying computerized systems and decision-making algorithms to urban management (2015). According to Glasmeier and Christopherson (2015), the contemporary Smart Cities are more of the latter – they are not simply a place with high-tech sectors, but more importantly a place transformed by those technologies.

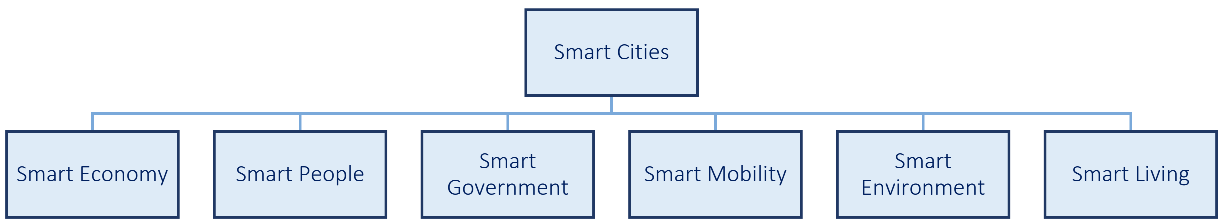
The concept gained popularity in academia, business, and government, each addressing different perspectives of how Smart Cities can improve the Quality of Life in terms of social, economics, and sustainability challenges. Therefore, the Smart Cities concept has various definitions. To find the essential elements underpinning the Smart Cities regime, a group of scholars studied 5,553 Smart Cities around the world through a webometric exercise, identifying five emergent critical junctures in the Smart Cities discourse: Socio-Technical Bifurcation, Transformative Change Versus Incremental Optimization, A Place, Project, Or Phase?, Public-Private Partnership, and Smart And Sustainable (Joss et al., 2018). Their study indicates that cities are in the phase of deciding between technical-driven "smartness" and social-driven "sustainability".

Since this research focuses on the general impact of Smart Cities implementation, this paper revises and adopts a relatively comprehensive definition from Caragliu et al. (2009): Smart cities is a system where social and human capital as well as ICT infrastructure are under wise and participatory governance to improve Quality of Life and achieve sustainable economic growth. Smart Cities initiatives, accordingly, refer to the collaborative efforts in achieving the Smart Cities vision.

Smart Cities Framework

As mentioned in the definition, Smart Cities vision is inseparable from both capital and infrastructure. As great social and human capital builds great ICTs infrastructure, the Smart Cities infrastructure in turn helps cultivate smart capital (Voda and Radu, 2018). Both of them are associated with different social actors including government agencies, private businesses, and civilians, as well as different elements of urban living. While urban living involves many industries, from education to environment, most cities' initiatives have explicit strategic framework, structured by either development sectors or technology areas (Angelidou, 2017). Giffinger and Gudrun (2010) identified 31 relevant factors from literature and a round-table-discussion, and categorized them into six smart characteristics: economy, people, governance, mobility, environment, and living. Specifically, they listed Smart Mobility with Transport and ICT, with factors including local accessibility, (Inter-)national accessibility, availability of ICT-infrastructure, as well as sustainable, innovative and safe transport systems. Their framework (see Figure 1) uses a top-down approach to unfold the broad concept of Smart Cities, making Smart Cities an umbrella of seemingly disparate sectors.

FIGURE 1. SMART CITIES FRAMEWORK



SOURCE: GIFFINGER & GUDRUN (2010)

Yet from a different perspective, say one smart technology, could be connected to more than one smart sectors; and a sector could be associated with other sectors as well. Even though this paper focuses on transportation which would be under Smart Mobility, concepts of other sectors are also discussed because of their associable nature.

The Inter-American Development Bank (IDB) looked at ten Smart Cities around the world and took a similar top-down approach as Giffinger and Gudrun by identifying six key smart city service spectrums, including Transportation and Urban Mobility, Safety and Citizen Security, Emergency and Response, Environment, Energy Efficiency, and Citizen Interaction and Communication (Lee et al., 2016). Both articles demonstrate that different sectors are in fact different viewpoints of how Smart Cities initiatives are developed to tackle social, economics, and sustainability challenges. To study the effectiveness of Smart Mobility implementation in specific cities, this research draws attention to the objectives of Smart Mobility initiatives and the impact of relatively new transportation technologies.

TRANSPORTATION AND SMART TECHNOLOGIES

ICTs have both direct and indirect impact on transportation challenges. For example, technologies such as Radio Frequency Identification (RFID) on gantries and speed cameras are used to improve quality of commute by regulating speed and reducing crashes. The shared ICTs infrastructure could enable congestion pricing and virtual service requests to promote fairness and accessibility. These technological reforms could also affect people's travel behaviors and make transportation more sustainable.

Particularly, plenty of research in the forms of data analysis and literature review has been conducted by scholars to examine ICTs' impacts on people's travel behaviors, as in whether ICTs would increase or decrease travel activities for certain means or purposes of travel. Even though there is a significant amount of literature showing that ICTs have impact on travel behaviors, the overall impact remains inconclusive. For the heavily researched shopping trips, some scholars suggest that motorized trips could be substituted by online purchases (Kenyon, 2006; Anderson, Chatterjee, & Lakshmanan, 2003), while the others find a complementarity relationship between internet usage and motorized trips (Hong & Thakuriah, 2016; Visser & Lanzendorf, 2004; Winslott Hiselius, Smidfelt-Rosqvist, & Adell, 2015).

For sustainability as in changes in means of transportation, a study (Yigitcanlar & Kamruzzaman, 2019) about Smart Cities and mobility in Australia suggests that the extent of public and active transport use decrease with access to broadband internet. On the contrary, some (McDonald, 2015; Wu, Hong, & Thakuriah, 2019) find that increasing adoption of ICTs is associated with declination in motorized travel. McDonald's models also reveal that both demographic shifts and millennial specific factors are responsible for the declines in automobile mobility. Another finding reveals that online shopping activities reduce CO_2 emissions and further demonstrates that increasing use of ICTs will shape a more sustainable travel pattern (Rosqvist and Hiselius, 2016).

In addition, ICTs are also closely related to social equity and human capital. Lavieri et. al. (2018) propose an important idea that activity-travel choices are consequences of individual, household, and work characteristics that are mediated by virtual and physical accessibilities which are determined by socioeconomic factors, including age, income, gender, occupation, education, family status, vehicle ownership, residence location, race, and nationality. Their findings suggest that virtual accessibility and physical accessibility jointly influence virtual activity and physical activity, and ICTs' impact on offline mobility is small. Their study also imply that physical accessibility is more influential than virtual accessibility to people's activities.

Although not straightforward, ICTs are likely to increase transportation activities especially in urban area. Smart cities show promises to promote sustainable travel-activity and potentials for social equity. For example, Smart Cities initiatives could implement "people and culture" programs to resolve privacy concerns and invest in virtually-marginalized groups. In this case, governmental initiatives and regulations on such technologies would have a determining effect on their impact. Connected to environmental, social, and economics challenges, transportation-related technologies paired with effective policies is a strategic opportunity to help cities reach their goals.

Analysis and Discussion

Methodology

Reviewed literature of different countries and scale underscores that Smart Mobility initiatives can impact travel behavior, sustainability, and social equity. To investigate the purpose and effectiveness of Smart Mobility implementation more concretely, a comparative case study of Singapore and Chicago are conducted. These two cities are selected to demonstrate Smart Cities implementations in two sociopolitical environments. Besides availability of data, Singapore was selected because it is a renown progressive Smart City. Located on an island with high population density, it faces tremendous environmental challenges. Its vision seeks to harness ICT, network and data to support better living and alleviate urban challenges (Lee et al., 2016). Its transportation and mobility sector is also the most developed Smart Cities service in Singapore and around the world. Chicago was chosen because although compared with Singapore it is at its early stage of building their version of smart city, it is ranked first out of four North American cities with best urban transport systems (Knupfer et al., 2018). Despite differences between the two sociopolitical environment and various Smart Cities programs, comparing these two cities would produce generable knowledge about how Smart Cities implementations work and impact cities. As a result, three aspects of both cities are discussed and each aspect is analyzed in regards of one Smart Mobility product. Finally, the similarities, differences, and patterns across the two cases are summarized.

Singapore

Introduction

Singapore is renowned for being the first city to adopt an Electronic Road Pricing (ERP) system (Menon & Guttikunda, 2010). Due to limited land area, the city faces the challenge of growing transportation need. Despite congestion pricing was politically unpopular (The Case for Electronic Road Pricing, 2016), road pricing was first implemented in the form of the Area Licensing System (ALS) in 1975. To drive into the Central Business District (CBD), motorists have to purchase a license from post office, gas station, or convenience store and then stick the license on the windshield. There was law enforcement at the entry of all priced roads and any violations would be charged a ticket in two weeks. Around the 1990s, Singapore added a Road Pricing System (RPS) for congested roads on three main highways to further control their congestion level. However, they have become labor intensive and prone to errors. The flat fee per license was also critiqued to be not equitable enough.

In 1998, the old road pricing system was replaced by the Electronic Road Pricing (ERP) system, which relies on the Radio Frequency Identification (RFID) technology on an in-vehicle unit (IU) and gantries. It allows for a more effective and flexible method of speed measurement and congestion charging. Managed by the Land Transportation Authority of Singapore (LTA), the RFID technology used supports an automatic congestion rate calculation based on traffic flow. It charges every vehicle passing under a road pricing gantry during its operating hours through motorists chosen payment method including credit/debit card. The cost of ERP was $197 million for its debut and $25 million for annual operation and maintenance. In 2008-2009, the annual revenue was estimated at $144 million. In 2016, The Land

Transportation Authority announced that Singapore's next-generation road pricing system (ERP2) will debut in 2020 (Tan, 2016).

Goals and Objectives

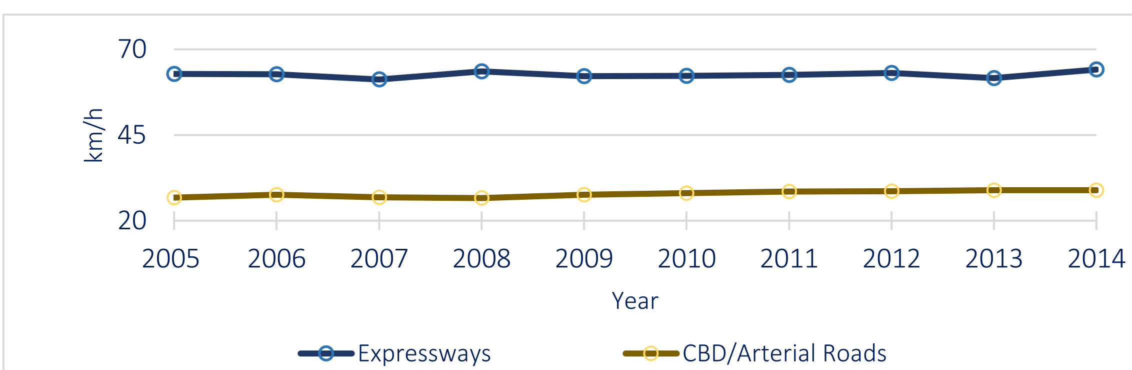
By pricing congested roads and charging those road users, the ERP system primarily aims to provide a solution for congestion pricing (MOT Singapore – Gain new perspectives on land, sea & air transport, n.d.). Congestion pricing is a way of managing traffic congestion and optimizing road network in order to enhance people's commute experience without building too many roads. The Ministry of Transportation (MOT) also incorporates that this initiative encourages motorists to consider switching their time, route or mean of travel, thus promoting more sustainable travel patterns such as public and active transportation. In addition, as charges on selected roads are determined by usage, the system is considered fairer because those who contribute more to congestion pay more.

Quality of Commute: ERP and Traffic Flow

The key objective of Smart Mobility would be to promote quality of commute. In order to reduce congestion and optimize traffic flow, as one of the goals and objectives for ERP, Singapore adopted the Electronic Road Pricing system that uses electronic gantries to detect the speed of vehicles. This system with the RFID technology enables the government authority to monitor real-time traffic speed and calculate congestion pricing. According to the Ministry of Transport of Singapore (MOT Singapore – Gain new perspectives on land, sea & air transport, n.d.), "since its introduction, the ERP system has been effective in managing traffic congestion and keeping traffic speeds within the optimal range." It has increased average speeds from 30-35 KPH to 40-45 KPH (18-22 MPH to 24-28 MPH) (U.S. Department of Transportation - Federal Highway Administration, n.d.).

According to a case study from Development Asia, traffic volume has stayed below 1975 levels (The Case for Electronic Road Pricing, 2016). More specifically, traffic flow in Singapore between 2005 and 2014 is represented by Figure 2 showing average speed of traffic during peak hours. Even though the ERP system has been effective since 1998, only traffic flow data that are after the year of 2005 are available on the LTA website (LTA | Who We Are | Statistics & Publications | Statistics, n.d.). Despite the absence of concrete before and after data, the increasing speeds from 2005 to 2014, from 62.8 km/h to 64.1 km/h

FIGURE 2. AVERAGE SPEED OF TRAFFIC DURING PEAK HOURS IN SINGAPORE, 2005-2014

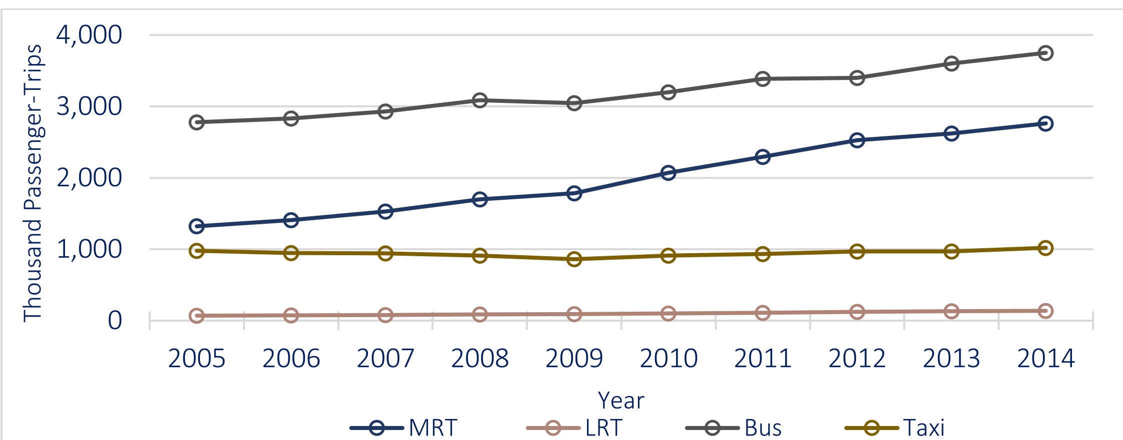


SOURCE: STATISTICS AND PUBLICATIONS BY LAND TRANSPORTATION AUTHORITY on expressways and from 26.7 km/h to 28.9 km/h on CBD/Arterial Roads, demonstrate better traffic flow with the ERP congestion pricing system. It is worth noting that to maintain smooth traffic flow, besides establishing the ERP system, Singapore also invest in vehicle ownership control measures, road capacity optimization, and increasing public transport use.

Sustainability Challenge: ERP and Motorized-Vehicle Usage

Because of growing environmental challenges, another goal of Smart Mobility initiative is to lessen motorized-vehicle usage. The ERP system has been implemented to tackle this challenge by incentivizing motorists to switch time, route, or mode of travel. By charging "extra" for driving, the system aims to encourage the public to switch from private vehicle to public or active means of transportation. Meanwhile, Singapore has been reducing the cost and improving public transport infrastructure to develop alternative means of transportation, which has successfully reverse the decreasing public transport ridership since 1997 (The Case for Electronic Road Pricing, 2016). According to a report by a non-profit organization (A Way Forward For New York City: Road Pricing in London, Stockholm and Singapore, 2018), this ERP system has enabled public transit improvement and the bus and train ridership increased by 15% as a result. It has also reduced carbon dioxide and other greenhouse gas emissions by 10-15%. Data from the LTA website, as shown below in Figure 3, confirm that ridership for both Mass Rapid Transit (MRP) and Light Rapid Transit (LRP) has been growing steadily from 2005 to 2014 (LTA | Who We Are | Statistics & Publications | Statistics, n.d.).

FIGURE 3. AVERAGE DAILY RIDERSHIP IN SINGAPORE, 2005-2014



SOURCE: STATISTICS AND PUBLICATIONS BY LAND TRANSPORTATION AUTHORITY

Social Challenge: ERP and Equitable Pricing

As the flat rate of ALS was considered inequitable (The Case for Electronic Road Pricing, 2016), it is important for the ERP system is to be fair. As a result, the equity of the system is demonstrated through a progressive charge as the social cost of driving. Unlike ALS, charges under the ERP system are based on usage. Those who contribute more to the congestion pay more. Those who use the roads less frequently or travel during non-ERP hours will pay less or do not need to pay at all.

One Motoring, a website portal by LTA, offers comprehensive vehicle-related information and digital services, including for the ERP system. During the ERP operational hours which is usually 7 am – 8 pm Monday - Saturday, ERP rates are generally determined for every half-hour period (Electronic Road Pricing (ERP) | Driving | One Motoring, n.d.). To keep traffic speed at an optimal range of 20-30 km/h on arterial streets and 45-65 km/h on expressways, the rates are adjusted for every period. The ERP rate also depends on the type of vehicles and bigger vehicles pay more. For passenger cars/lights goods vehicles/taxis, as of February 10, 2020, the rates during operational hours range from S$0.00 to S$3.00. For comparison, its average hourly salary in 2020 is S$34.38, with a range of S$4.79 to S$157.08 (Average Salary in Singapore 2020—The Complete Guide, n.d.). Obviously, it is less of a financial burden for the wealthy to enjoy the optimal traffic flow. Nevertheless, this initiative is perceived as far from unfair given that citizens have been generally satisfied with the system since they have the option to select other route, time, or means of travel (U.S. Department of Transportation - Federal Highway Administration, n.d.).

Lessons and Limitations

In summary, evidence supports that the ERP system has advanced Singapore's Smart Mobility initiative. It has ensured better traffic flow since it was first implemented, introduced fairer charges for driving, and also invested in multi-modal transportation to grow public transport ridership. There are valuable lessons from its success.

The accomplishment of the system is extremely dependent on the leadership of one central authority - LTA. Because of LTA's strong influence, every component under this program is able to share information and inform decision-making in, for example, setting real-time ERP rates. LTA is supported by two operations centers 24/7 to monitor and collect real-time traffic data. LTA also pays attention to a great variety of services and publicity of information, from rail extension to vehicle services. It stresses on a collaborative Smart Mobility sector and also push to update policies and programs.

Singapore is also willing to sacrifice short-term revenue and even popular opinion to enable substantial changes. Despite huge cost and unpopularity of congestion pricing, LTA adopted the system and put endeavors to it. In order to raise awareness, increase acceptance, and educate users, a lot of resource has been invested into not only the infrastructure but also various forms of service instructions.

On the other hand, LTA's strong leadership limits the extent of open and free information and perhaps negative critiques available. The governmental reports are simplified and may be filtered to highlight positive results. Primary data are hard to find. Since the project has a rich history, it was improbable to compare before and after data of the ERP system. Additionally, LTA's exhaustive approach to Smart Mobility may also magnify the direct impact of the ERP system, since the traffic data representing the impact of the ERP system could also be affected by other technologies and programs.

Chicago

Introduction

As one of the biggest cities in the United States, Chicago, with great ambition, is maturing at its early technical-driven stage of building their version of smart city. The Chicago Tech Plan unveiled under the

Emanuel administration visions Chicago a city fueled by technology. It highlights five fundamental strategies: Next-Generation Infrastructure, Every Community a Smart Community, Efficient, Effective, And Open Government, Civic Innovation, and Technology Sector Growth (City of Chicago, 2013). In September 2019, Mayor Emanuel convened the Chicago New Transportation and Mobility Task Force to "ensure Chicago remains on the forefront of urban transportation and mobility innovation (City of Chicago, 2019)." In the report, he stresses on the importance of advancing infrastructure to combat the challenges of climate change, urban equity, adoption of mobility innovations as well as to accelerate economic opportunity.

Indeed, even though Chicago has been posited as a leader in road infrastructure, private transportation efficiency, public transit comfort and affordability, and the availability of digital ticketing (Knupfer et al., 2018), the city has been coping with technology disruption and social concerns. ICTs innovation in Transportation Network Providers (TNP) has increased ride-hailing by 271% between 2015 and 2018 while bus ridership has declined 28% since 2008 (Freund, 2019). The city is looking forward to expand its existing Divvy bikeshare system to promote shared micro-mobility options and encourage equitable fees to promote inclusion (City of Chicago, 2013). Moreover, Emanuel's speed camera program is notorious for using safety protection as a cover for bribery and revenue generation (O'connor, 2020). According to a Chicago Tribune investigation, the program improperly issued more than $2.4 million in fines to Chicago drivers (Kidwell & Epton, 2015), causing citizens to distrust such initiatives. Some older technologies, such as the 311 city services, although long-standing, could reflect equity problems associated with sociodemographic characteristics of residents.

Goals and Objectives

Chicago's New Transportation and Mobility Task Force Report conveys the goals and objectives of its transportation system through a list of principles shown in Figure 4. These principles contain multiple underpinning elements, including transportation system, mobility choices, economic development, global competiveness, design guidelines, and regulation of private providers. They convey the objectives as safe, equitable, innovative, efficient, reliable, sustainable, and beneficial to the public through their adjectives. This case study looks at three Smart Mobility programs in Chicago, including speed cameras, Divvy bikeshare, and 311 transportation service requests, with respect to safety, sustainability, and equitability.

FIGURE 4. PRINCIPLES LISTED IN CHICAGO'S MOBILITY TASK FORCE REPORT

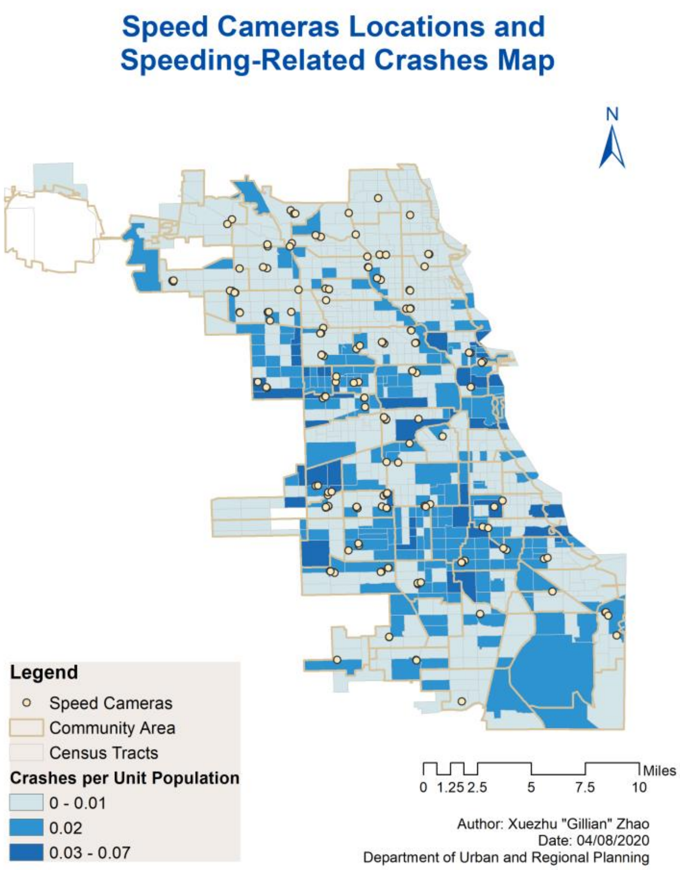
Principles for government leaders and stakeholders to follow when developing policy, planning for infrastructure, launching programs and pilots, and studying new innovations and services	A transportation system that is safe for all users
	Mobility choices that are accessible, equitable, affordable and non-discriminatory
	Economic development that is inclusive and innovative
	A city that is efficient, smart and reliable
	Communities that are sustainable, healthy, and built using universal design principles
	Regulation of private providers that is guided by public benefits

SOURCE: CITY OF CHICAGO (2019)

Quality of Commute: Speed Cameras and Safety

Quality of commute is tied to optimization of travel safety and minimization of risk of crashes. Speeding is widely recognized as a factor contributing to both the possibility and the severity of road crashes and injuries (World Health Organization, 2004), therefore speed is regulated ubiquitously especially in bigger cities. Experts generally agree that implementing traffic surveillance measures such as speed cameras and speed signs are effective in controlling traffic flow and regulating speed (Boos, 2009).

FIGURE 5. MAP SHOWING LOCATIONS OF SPEED CAMERAS AND SPEED-RELATED CRASHES IN CHICAGO



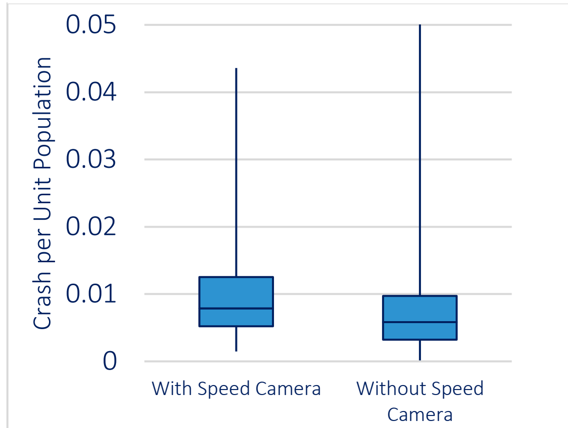
SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES)

Mayor Emmanuel's speed camera program was approved by Chicago City Council in 2012, aiming to bring safety to the community (Kidwell & Epton, 2015). Administration officials state that the cameras are placed at streets with the biggest safety problems based on crash statistics. However, this program was proven by the Chicago Tribune to be erroneous (Mack et al., 2012).

To examine the effect of speed camera, this study collected publicly available data on Chicago Data Portal for speed cameras locations and traffic crashes from Oct 19, 2017 to Dec 14, 2017. Of all traffic crashes, primary causes that are related to speed include: "failing to reduce speed to avoid crash" (4.2%), "exceeding authorized speed limit" (0.5%), and "exceeding safe speed for conditions" (0.4%). In fact, speed-related reasons only contribute to a small percentage of crashes. For the same time period, besides causes that were "unable to determine", the most common primary cause for crashes was "failing to yield right of way" (11%), followed by "following too closely" (11%). Driving etiquette should be more of concern than speed regulation. To understand the connection between speed-related crashes and speed cameras, Figure 5 shows the locations of speed cameras with yellow circles as in Feb 12 2020 in Chicago, as well as the possibility of speed-related traffic crashes by census tracts indicated by three shades of blue. The possibility of speed-related traffic crashes is also calculated with crashes data available on the Chicago Data Portal from Oct 19 2017 to Dec 4 2019 that are filtered by primary cause and normalized by population. It is shown that speed cameras are evenly distributed across the city, and are present at census tracts with higher and lower risks of speed-related crashes.

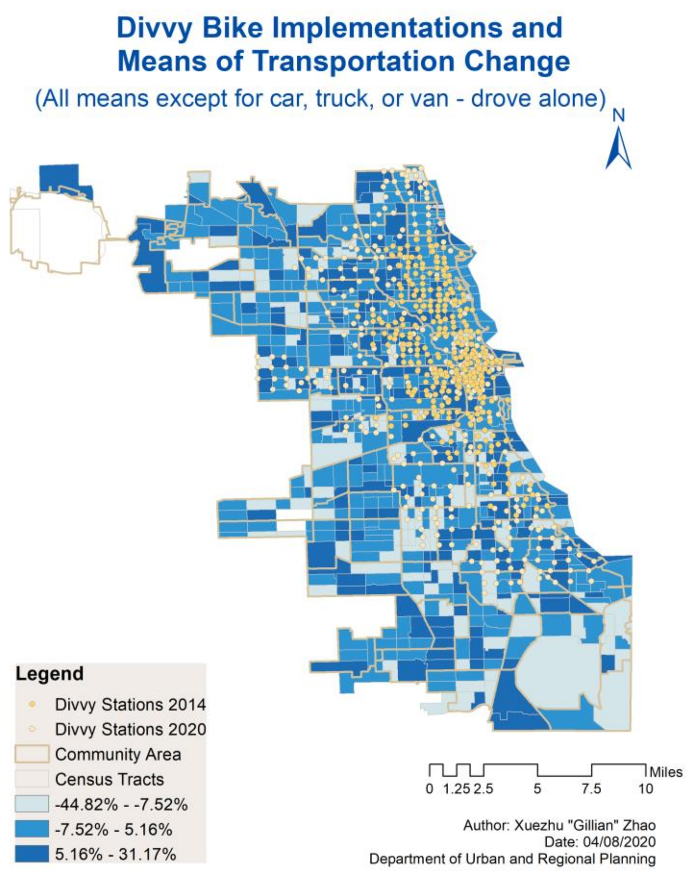
To examine the impact of speed cameras, the speed-related crashes data are separated into two groups based on whether the census tract has speed camera or not. Figure 6 illustrates the pattern of crashes possibility and indicates that crashes are more likely to occur at tracts with speed camera. Since the speed camera program has been launched since 2012, even though the location of speed cameras could have been changed, residents should have been aware of the existence of the program. However, it is interpreted from the analysis that speed cameras have been ineffective in minimizing speed-related crashes in Chicago. This corresponds with the Chicago Tribune's investigation conclusion. This suggest that either the location or the usage of the speed camera programs is not ideal to enhance or protect traffic safety.

Figure 7. Box plot of crashes data for tracts with and without speed cameras



SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES)

FIGURE 6. MAP SHOWING DIVVY LOCATIONS AND "SUSTAINABLE TRAVEL BEHAVIOR" CHANGE BY CENSUS TRACTS



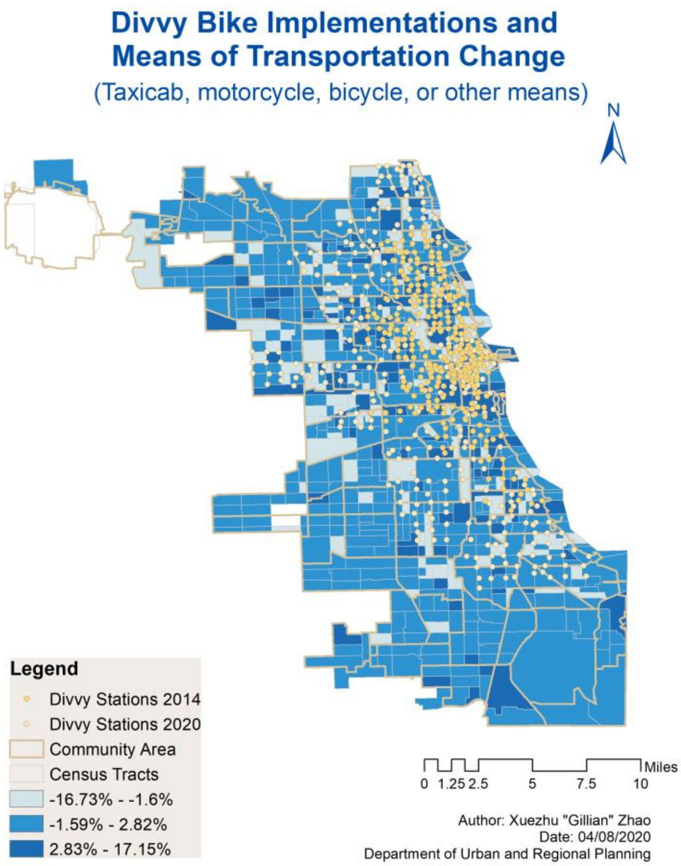
SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES AND 2008-2012 AMERICAN COMMUNITY SURVEY)

Sustainability Challenge: Divvy Bikeshare and Sustainable Travel

Citing a Mckinsey & Company report, private vehicles are heavily used by Chicago residents, albeit having a well-developed transit system (Knupfer et al., 2018). Sustainable travel methods, including active transportation, public transportation, and ride-sharing, should be promoted within mobility choices. Ideally, Smart Mobility implementations should increase the percentage use of sustainable travel methods. As a representation of the smart technology, Divvy bikes have been implemented in Chicago since 2013. By comparing the means of transportation change of census tracts with and without Divvy bike stations, this study examines if Divvy bike implementations have positive influences on sustainable travel.

Sustainable travel behavior is represented by the percentage of

FIGURE 8. MAP SHOWING DIVVY LOCATIONS AND "BIKING BEHAVIOR" CHANGE BY CENSUS TRACTS



SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES AND 2008-2012 AMERICAN COMMUNITY SURVEY)

population not driving alone as well as the percentage of population using bicycle. The mean of biking is the best representation of the effect of Divvy bike implementation, but due to limitation of ACS data, data for all means except for car, truck, or van – drove alone are used to represent the general "sustainable travel behavior"; and data for taxicab, motorcycle, bicycle, or other means are used to signify "biking".

Comparing 2014-2018 ACS data with 2008-2012 ACS data, the change in general "sustainable travel behavior", as shown in Figure 7, ranges from a decrease in 44.82% to an increase in 31%. The changes are classified into three groups: negative, minimal change, and positive, represented by different shades of blue. The hypothesis is that census tracts with Divvy bike stations will encounter more significant increases in sustainable travel behavior after the Divvy program implementation in 2013. As shown in table 1, 66.25% of the census tracts with Divvy stations since 2014 shows increases and 61.63% of the census tracts with Divvy stations in 2020 shows increases. Compared the census tracts with Divvy stations with those without Divvy stations for both 2014 and 2020, even though the changes for the older tracts are more significant, both comparison groups show that more percentage of residents of census tracts with Divvy stations adopted sustainable travel methods than those of census tracts without Divvy stations.

The same conclusion is generated from changes in "biking" data. Comparing 2014-2018 ACS data with 2008-2012 ACS data, the change in percentage resident "biking", as shown in Figure 8, ranges from a decrease in 16.73% to an increase in 17.15%. The changes are classified into three groups: negative, minimal change, and positive, represented by different shades of blue. More percentage of residents of census tracts with Divvy stations adopted biking as a mean of transportation than those of census tracts without Divvy stations.

TABLE 1. PERCENTAGE OF CENSUS TRACTS SUGGESTING INCREASES IN SUSTAINABLE TRAVEL BEHAVIOR SINCE 2008-2012

Tracks	2020		2014	
	With Divvy Stations	Without Divvy Stations	With Divvy Stations	Without Divvy Stations
"Sustainable Travel Behavior" Increases	61.63%	48.85%	66.25%	50.86%
"Biking" Increases	59.75%	49.48%	68.75%	49.76%

SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES AND 2008-2012 AMERICAN COMMUNITY SURVEY)

In addition, four t-test statistical analyses between the data for tracts with or without Divvy stations in 2014 and 2020 are conducted, for both general "sustainable travel behavior" and "biking" (see Table 2). All of the null hypothesis, which is change in sustainable travel in a census tract is not associated with presence of a Divvy station, are rejected. Though, margin of error of American Community Survey Estimates data is unaccounted for, meaning that there could be sampling error associated with the estimates. With small differences between the estimates, they may not represent a true difference within the full population. The results illustrate that having Divvy stations on the census tract might have indirectly supplemented rather than directly prompted people to adopt sustainable travel behaviors to commute to work, and that the chance factor cannot be ruled out.

TABLE 2. T-TEST ANALYSIS BRIEF PROCESS AND RESULT OF TRAVEL BEHAVIORS CHANGE

		2020			**2014**		
		With Divvy Stations	Without Divvy Stations	Difference between Stations	With Divvy Stations	Without Divvy Stations	Difference between Stations
	N	318.00	481.00		160.00	639.00	
2018	Percentage Sustainable Travel Mean	58.31	44.12	14.20	63.94	46.22	17.72
2012	Percentage Sustainable Travel Mean	56.42	44.39	12.03	61.00	46.22	14.78
	Change across Years	1.90	-0.27		2.94	0.00	
	T-Test Result (One-Tailed)	**T-value 2.99 P-value 0.00**			**T-value 3.87 P-value 0.00**		
2018	Percentage Biking Mean	4.47	2.39	2.08	5.71	2.59	3.11
2012	Percentage Biking Mean	3.37	1.94	1.42	4.17	2.10	2.07
	Change across Years	1.10	0.45		1.54	0.50	
	T-Test Result (One-Tailed)	**T-value 2.79 P-value 0.01**		**0.01**	**T-value 3.57 P-value 0.00**		

SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES AND 2008-2012 AMERICAN COMMUNITY SURVEY)

In addition, it is apparent that the data for 2020 do not seem as convincing as those for 2014. It is because Divvy bike first started at the more affluent areas in Chicago, as illustrated in table 3. The first implementations of Divvy stations, located at the northeast side of the city, has 31% minority, 15% under poverty line, 11% without internet access, and 67% received higher education. Compared these to the average condition, it is obvious that the stations are located at the better-off areas. In 2020, it is perceived that the stations are implemented to underserved communities with more people of color and higher poverty rates. This gives hope to a more equitable development and implementation of Divvy bike as well as a more environmental friendly way of travel throughout the city.

TABLE 3. SOCIODEMOGRAPHIC CHARACTERISTICS OF CENSUS TRACTS WITH AND WITHOUT DIVVY STATIONS IN 2020 AND 2014

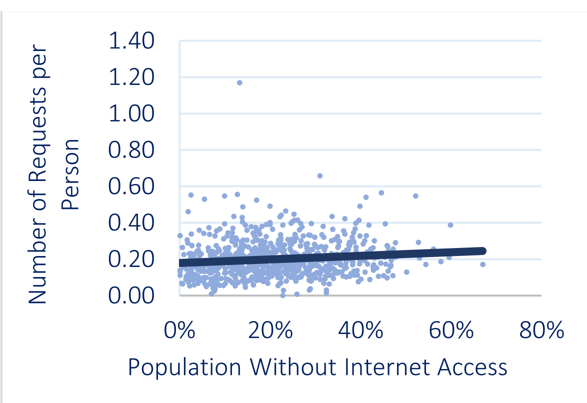
	2020		2014		
	With Divvy Stations	Without Divvy Stations	With Divvy Stations	Without Divvy Stations	Mean
People of Color	46.38	56.12	31.37	57.47	52.24
Under Poverty Line	20.82	21.19	14.84	22.78	21.19
Without Internet Access	18.16	21.07	11.06	23.58	21.07
Received Higher Education	48.84	35.85	67.44	27.94	35.85

SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES AND 2008-2012 AMERICAN COMMUNITY SURVEY)

Social Challenge: 311 Service Platform and Social Equity

Chicago was the first municipality to launch a comprehensive 311 system in the United States, offering a "one-stop shopping" experience for all city services and non-emergency police services (Chicago 311 History, n.d.). Its web-based routing system connect residents with service requests to a corresponding department for solution. When it comes to transportation services, including pothole complaint, street light out complaint, and so on, the 311 Service Request platform takes care of them. Residents can either call 311 or go to 311.chicago.gov to file their service requests for which Chicago Department of Transportation (CDOT) can take care.

FIGURE 9. SCATTERPLOT WITH A LINE OF BEST FIT TO DEMONSTRATE THE RELATIONSHIP BETWEEN INTERNET ACCESS AND SERVICE REQUESTS



SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES)

The 311 system is designed to bring convenience for residents to access city services. Because some communities have a lower level of internet access (Zamudio, 2018), it is hypothesized that people with internet access will file more service requests, since they are given an additional option to file any requests. A study researching about 311 complaint volumes between over-reporting and under-reporting groups in New York City finds that socioeconomic status, household characteristics, and language proficiency have an unneglectable effect on the residents' propensity to use 311 across

New York City (Kontokosta et al., 2017). Specifically, they find that neighborhoods that have a higher percentage of male, unmarried, limited English-speaking residents and higher unemployment rate tend to under-report; while neighborhoods with higher rents, income, education attainment and a higher percentage of female, elderly, non-Hispanic and Asian residents tend to over-report. Based on their findings, the hypothesis for the equity condition in Chicago will be similar to that in New York City.

To investigate whether transportation service request platform is equally accessible and how services are requested by different tracts, transportation service requests are filtered out from all service requests, from July 1 2018 to February 4 2020, on the 311 data platform. The top 5 transportation service requests are: Street Light Out Complaint (31%), Pothole in Street Complaint (26%), Sign Repair Request – All Other Signs (11%), Alley Light Out Complaint (9%), and Traffic Signal Out Complaint (8%). From 2014-2018 American Community Survey 5-Year estimates data, percentage of population without internet access, percentage of population that are people of color, percentage of population under poverty line, and percentage of population with college degree and above are selected to represent the socioeconomic characteristics of census tracts. First, a regression analysis for the relationship between number of transportation service requests per person and percentage of population without internet access by census tracts is conducted. With an adjusted R square of 0.01 and a coefficient of 0.10, the result suggests that there is no relationship between limited internet access and 311 transportation service requests could be accounted for people's access to transportation services. Even though it is an instinctive hypothesis that limited internet access could hinder people from requesting transportation services, the influence of internet access is insignificant because the factors for requesting transportation services are much more complex. The data not only represent the use of these services but also signify the demand for these services, which is tied to the condition of infrastructure.

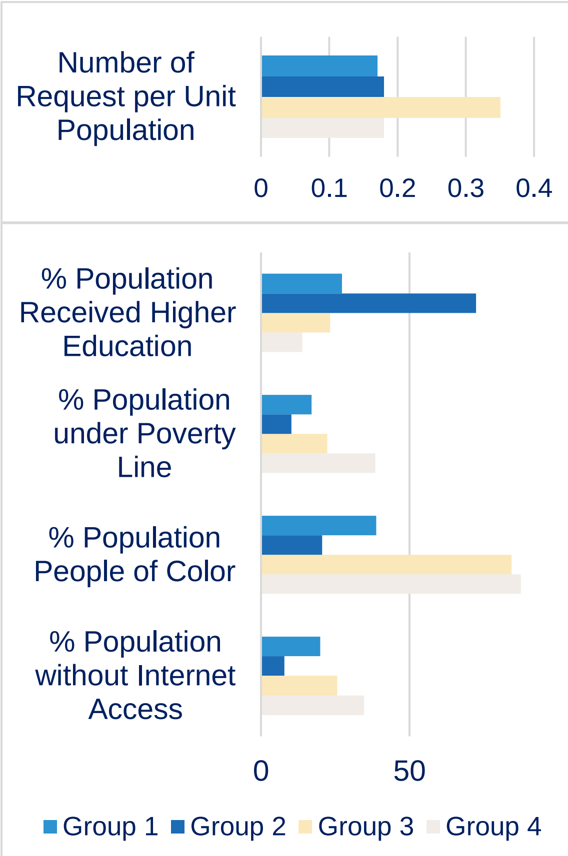
Referencing the correlation table (Table 4), limited access to internet is positively associated with poverty level, positively associated with people of color, and negatively associated with higher education attainment. In this way, any acts that associate the location with infrastructure improvement might hinder the maintenance of certain areas or certain groups of people, jeopardizing the development of an equitable smart city. Therefore, it is important to look at the existing conditions to examine the geographical distribution of service requests by census tract along with socioeconomic factors.

TABLE 4. CORRELATION BETWEEN SOCIODEMOGRAPHIC CHARACTERISTICS FOR ALL CENSUS TRACTS

Percentage Population	Without Internet Access	Minority	Under Poverty Line	Received Higher Education
Without Internet Access	1.00			
People of Color	0.66	1.00		
Under Poverty Line	0.66	0.69	1.00	
Received Higher Education	-0.76	-0.62	-0.55	1.00

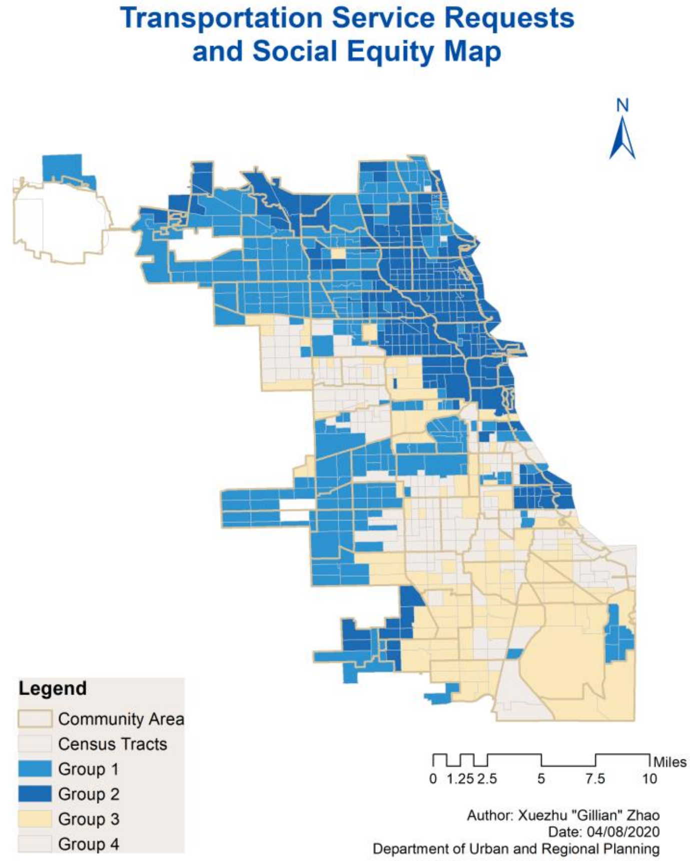
SOURCE: U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES)

FIGURE 10. SOCIODEMOGRAPHIC FEATURES OF FOUR GROUPS



SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES)

FIGURE 11. MAP ILLUSTRATING GROUPING ANALYSIS RESULT



SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES)

TABLE 5. MEANS OF ATTRIBUTES FOR EACH GROUP

	Number of Requests per Person	% Population without Internet Access	% Population Minority	% Population under Poverty Line	% Population Received Higher Education
Group 1	0.17	19.95	38.84	17.05	27.24
Group 2	0.18	7.93	20.59	10.20	72.45
Group 3	0.35	25.61	84.38	22.37	23.24
Group 4	0.18	34.71	87.47	38.51	13.91

SOURCE: CITY OF CHICAGO (2020) AND U.S. CENSUS BUREAU (2014-2018 AMERICAN COMMUNITY SURVEY 5-YEAR ESTIMATES)

In order to examine the pattern of how socioeconomic factors and transportation services are correlated and potentially influenced by Smart Mobility infrastructure condition, census tracts are grouped through Grouping Analysis based on their features including number of requests per person, percentage population without internet access, percentage population that are people of color, percentage population that are under poverty line, and percentage population with college degree and higher with no spatial constraints and random seeds. This method uses K Means algorithm which compares data points to each other in order to make the data points within one group as similar as possible and all the groups themselves as different as possible. In this case where four groups were specified, the Transportation Service Requests and Social Equity Map illustrates the grouping result as shown in Figure 10. Figure 11 and Table 5 document the mean of each attribute represented for each group.

These results signify that first, the city itself is pretty segregated in terms of internet access, race, income, and education attainment; secondly, even though internet access may not have an influence on requesting transportation services, the grouping analysis result suggests potential narratives for how different sociodemographic characteristics are related to people's demand for 311 transportation services.

Looking at each group's service request data, group 3 appears to be a significant outlier which signifies the over-reporting census tracts. It has 114 census tracts with significantly higher number of requests per person, while those for group 1, 2, and 3 are relatively similar. Compared with other groups, the census tracts in group 3 have lower internet access, higher percentage of people of color, higher percentage of population under poverty, and lower percentage of population with higher education. This contracts part of the finding of the New York City study that the less fortunate people are requesting and demanding more transportation services in Chicago. This could also suggest that the transportation infrastructure at those tracts is the most problematic.

Noticeably, even though group 2 and group 4 have identical means of requests per person, their sociodemographic attributes are significantly different. Group 2 has the highest internet access, the least percentage people of color population, the least percentage population under poverty, and the highest percentage population with higher education. Group 4 has the lowest internet access, the highest percentage people of color population, the highest percentage population under poverty, and the lowest percentage population with higher education. This implies that either Group 2 and Group 4 are provided with equitable transportation infrastructure, or they have different demands for and accessibility to the services, that Group 4 could be under-reporting. Comparing group 3 and group 4, even though they both have relatively low internet access, their request per person data are different. Some residents of group 4 could be hindered by the lack of internet access and therefore not requesting 311 transportation services.

Lessons and Limitations

Based on the analyses, the programs transforming Chicago from a technology-driven "smartness" to a social-driven "sustainability" have both good and bad results. Concerning quality of commute, sustainability challenge, and service supply, the study chooses three transportation-related programs, including speed camera, Divvy bikeshare, and 311 service platform, to examine their impacts on safety, travel pattern and equity.

The impact Divvy stations have on sustainable travel behavior, although limited, suggests the benefit of bikeshare programs and sets an example for other cities to study. It also underlines the importance of a cooperative public-private partnership. To include underserved communities, Divvy has been implementing more stations. Even though the impact is not as significant after including the newer stations, it shows that both the city and the private company are adapting to a social-driven mobility vision. The effort put in making data transparent is impressive, especially important for the speed cameras case. Data from multiple sources could alarm fraudulent measures and call attention to unfair programs. For the case of 311 service platform, data generated could help cities identify approaches to improve technology and transportation infrastructure equitably.

The findings were not obtained without limitations. For the study of speed cameras' effectiveness, only crashes with speed-related causes were considered. The speed cameras could be helpful in identifying and preventing crashes of other reasons. In regards to sustainable travel behavior change, data for all means except for car, truck, or van – drove alone are used to represent the general "sustainable travel behavior" and data for taxicab, motorcycle, bicycle, or other means are used to signify "biking". This is unfortunately a major limitation that could lead to biased result since they do not accurately reflect what they represent. Moreover, because the 311 service request data do not indicate whether the requests come by phone or online, a more accurate relationship between lack of internet access and requests that come online could not be established. In this case, the relationship could be more significant than result indicated, but since 311 offers requests by phone, equity concerns by other sociodemographic are more important. A next step could be studying the transportation infrastructure condition for the under-reported and over-reported areas.

CONCLUSION AND RECOMMENDATIONS

Both Singapore and Chicago are using Smart Cities initiatives as a key strategy to become more competitive and develop sustainability goals. The comparative case study focusing on quality of commute, sustainability challenges, and social challenges find that while Singapore's smart program appear to achieve their visions to a great extent, Chicago has come a long way in making advancements and facing new challenges.

Singapore's success is demonstrated through its Electronic Road Pricing (ERP) system. Specifically, the study finds evidence that the traffic speed has been improved for those who paid, its road pricing system is an example of fair pricing, and its public transportation ridership has increased. The reasons behind these achievement, besides the long history for trials and improvement, are inseparable with its sociopolitical environment. The strong leadership of Land Transportation Authority (LTA) makes the implementation of programs especially effective. Nonetheless, there are no perfect initiatives. In this case, Singapore's data show low level of transparency. Despite literature and governmental reports manifesting it reaching its goals, there are limited evidence indicating its flaws. Due to the same reason, there are few studies indicating the contribution of the ERP system itself to the Smart Mobility vision. It is possible that other programs are more effective than the ERP system. Therefore, the ERP program along with other mobility programs should be carefully studied before being implemented to other cities, especially those under completely different sociopolitical environment. Moreover, the cost of implementation at its earlier stage for Singapore is incomparable – not every city should and could invest as much. The program's effective impact is also related to the huge effort spent on other aspects of Smart Mobility, including research, infrastructure, and education.

Unlike Singapore, open government is one of Chicago's important visions. Under disparate sociopolitical contexts, the development of Chicago's Smart Cities initiatives is driven by private research in technologies, managed by governmental institutions, and guided by transportation and Smart Mobility task force. As a result, the programs in Chicago are less concentrated, and their products tend to be heavily critiqued by media.

In terms of quality of commute, surveillance technology is at the heart of controlling both traffic flow and travel safety, with one regulating speed and the other detecting crashes. It is worth mentioning that even though speed camera is widely accepted and implemented in a lot of places, it is controversial in Chicago. The case study indicates the reason. Surprisingly, speed-related crashes are likely to occur at tracts with speed cameras, alluding to an explanation that the cameras were not placed at the right locations, contradicting the statements of government officials. This alerts people that it is possible to feign effective programs for political reasons rather than safety protections.

Both facing sustainability challenges, Singapore adopts the ERP system to disincentive driving private vehicles while Chicago works with Divvy to provide an innovative sustainable travel option. The analyses show that Singapore encounters rising ridership and Chicago sees growth in sustainable travel behaviors across the city. Due to limitation of data, the year-by-year implementation progress of the ERP system has not been explored, but it is certain that the ERP system could not be as successful without public transportation infrastructure improvement. Divvy bikeshare is also a commendable program as it has been expanding its services to provide opportunities to the underserved communities.

Under different sociopolitical contexts, both Singapore and Chicago address social equity problems. Singapore has added social cost and determined a fairer price for driving through the technology-enabled ERP program; Chicago's open data portal has enabled the public to investigate 311 transportation service request data and related equity problems. Of course, the concept of equity is different for every city, but the gap of wealth exists regardless. The ERP program favors the wealthy in terms of issuing congestion pricing, but LTA compensates the others by improving public transportation experience at the same time; the grouping analysis for Chicago reinforces its reputation as a segregated city, and shows that tracts with different sociodemographic characteristics have different demand for transportation services. With these programs, and the data that come with the programs, the cities could better understand the residents living different locations. For example, tracts in group 4 could be considered for a future Smart Mobility zone where pilot programs and ICTs infrastructure could benefit the communities and the city.

There is commonality across Singapore and Chicago's success and mistakes for future reference. First of all, public-private partnership is to be encouraged, for the purpose of connecting all pilot programs and private technologies together. Smart cities call for a unified data sharing structure, and private sectors themselves cannot realize the maximum amount of benefit without municipalities' effective decision-making. Secondly, educational programs helping residents accept and use Smart Cities programs are crucial to the effectiveness of smart programs. These are programs for social and human capital. Residents have to believe in them and given close instructions on how to use them. Thirdly, both cities were not hesitant to update their organizational structure, as Singapore launched the Government Technology Agency (GovTech) and Chicago established the transportation and mobility task force. Furthermore, governing bodies ought to work on data privacy legislations in correspondence of ICTs emergence. While they have undeniable advantages in aiding decision-making, smart programs record a large volume of data and often have surveillance features. Residents need to be protected by law before the programs become a part of daily life.

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