Determining the Feasibility of Traffic Management Through Mobile Applications in China

Hangzhou, China Project Center B'16

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Sponsor Liaison: Dr. Lu Huang
Zhejiang Smart City Research Center

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Abstract

The rapid urbanization of China causes traffic problems in its cities. This Interactive Qualifying Project (IQP) aims to determine the feasibility of improving Chinese traffic conditions by applying Smart City initiatives, specifically through mobile applications. The project researches the functions of popular mobile applications for traffic management in the United States and China. With guidance from our sponsor, Dr. Lu Huang of the Zhejiang Smart City Research Center, we surveyed the public from both countries. We explore the current traffic situations in the United States and China, and determine the feasibility of each application's function. This project provides direction for the development of future Chinese mobile applications and sustainable traffic management research.

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Executive Summary

Project Description and Problem

China, the world's most populous country, urbanizes rapidly in comparison to the rest of the world. Chinese cities are not initially built to expand, and therefore experience strains. One of these strains is traffic congestion. The population growth increases the number of vehicles on the road, and China implements solutions to tackle the subsequent traffic congestion. These solutions improve roadways, innovate public transportation, restrict road use, and designate bike and moped lanes. However, traffic continues to pressure Chinese cities and a new solution is necessary.

We explore Smart City initiatives as a solution to China's urban traffic issue. These initiatives embrace technology to improve human life with minimum resource consumption. We research previous Chinese traffic management solutions to propose a Smart City initiative. We investigate mobile applications as a possible Smart City initiative to lessen Chinese traffic congestion. Their key functions locate available parking locations, monitor traffic flow, report road hazards, and provide the most efficient travel route. These applications are more cost-effective than previous traffic management solutions in China. Although traffic management applications exist in China, they encounter legal obstacles and competition from private application developers internationally and domestically. Nevertheless, municipally owned applications are a possible solution to lessen traffic congestion.

Our project researches traffic management functions of mobile applications in the United States, and determines the feasibility of implementing them in China. The strengths from the United States applications outperform Chinese application functions. China can subsequently design and adopt mobile applications with similar functions to reduce traffic congestion.

Project Methods

Our project determines the feasibility of using traffic management functions of mobile applications from the United States to improve traffic conditions in China. We investigate the functions that make these applications effective. We choose four United States applications that represent these functions, and create a survey to investigate the respondents' desire for them. We determine four similar mobile applications in China, and conduct background research on their functions. To determine the Chinese population's knowledge and desire for effective applications, we create another survey based on the chosen application functions from the United States. We quantify the United States and Chinese survey responses. We conduct background research on Chinese regulations to examine legal obstructions in application implementation. From these findings, we provide recommendations to the Zhejiang Smart City Research Center.

Project Findings

We find that United States commuters drive personal cars as their primary mode of transportation. They are more aware of mobile applications with traffic congestion and hazard reporting functions than parking location and parking price functions. Chinese commuters use public transit as their primary mode of transportation, followed by personal cars. We find Chinese drivers spend longer times commuting shorter distances than United States drivers. Chinese commuters are less aware of parking location and pricing applications than traffic congestion and hazard reporting applications, but desire all four application functions.

Project Conclusions

Smart Cities constantly gather data, and mobile applications provide an ample source of data collection. We conclude that all four traffic management functions are feasible additions to upcoming Chinese mobile applications in Smart Cities. However, these functions require changes to perform successfully in China. China widely uses traffic congestion display applications, but requires a unified platform for collection of accurate data. Hazard reporting requires changing its data source to comply with Chinese regulations. Chinese drivers most desire parking availability and parking price applications, but these functions require improved user interface and advertisement.

Project Recommendations

We provide two recommendations to the Zhejiang Smart City Research Center based on our findings. The first recommendation suggests for the research center to investigate and propose the development of a unified parking application to the Traffic Management division of the Chinese government. This application combines the popular United States functions of parking location and parking price comparison. Our second recommendation to the Zhejiang Smart City Research Center suggests that they investigate and propose a unified traffic monitoring application to the Traffic Management division of the Chinese government. This unified traffic monitoring application combines the functions of traffic congestion display and hazard reporting. Collaboration between the research center and the Traffic Management division benefits both parties. These benefits include partial funding of the applications, installments of traffic management devices (i.e. parking sensors and roadway cameras), and collection of ample data to reduce traffic congestion.

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Methodology	Andrew Buley and Justin Shanahan
Results and Analysis	Gilberto Hernandez and Justin Shanahan
Conclusion and Recommendation	Gilberto Hernandez and Justin Shanahan
Appendices	Justin Shanahan and Justine Sherman
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All members of the Smart City Project Team edited each section of this report in full.

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1. Introduction

As technology changes, so do the needs of the people. Across the globe, technology pulls people from their rural lifestyles to settle in developing cities. As of 2016, China has 56% of the population living in urban areas (Zhao, 2016). This growing population density increases the number of vehicles on city roads, leading to higher traffic congestion. From 2005 to 2010, Chinese automobile production rose from approximately 13.8 million to 18.3 million cars (Jones, 2011). The simple method to manage the compounding traffic issue is to construct more roads. However, major old Chinese cities are not built to expand and must constantly find ways to accommodate their growing populations (Custer, 2016). Other methods include increasing public transportation, restricting road use, and encouraging other modes of transportation, yet these are not adequate solutions. To tackle the rapid increase of traffic, we ask the question of "how." How can China minimize its traffic congestion? How can China introduce a new method to confront this problem?

Smart City initiatives provide answers to these questions by embracing technology to improve city life with minimum resource consumption. Current Chinese infrastructure cannot satisfy their cities' growing demands. Major metropolitan areas in the United States and China use technology and apply Smart City initiatives to their public sector (Laouiti, 2015). These initiatives gather data on city living, including the amount of people driving cars, traffic light sequences, and highway driving speeds. Smart City initiatives place real-time numbers on cities' processes to tackle infrastructure's growing demands (Liu, 2014). We study these Smart City initiatives to derive a modern and practical method to address the problem of Chinese traffic congestion.

We consider examples of Chinese Smart City initiatives that tackle traffic to understand their effectiveness. These initiatives include expanding railway transportation, designating lanes for bike and moped use, and restricting the number of car registrations per year (BBC News, 2008).

Smart Cities use mobile applications as another initiative. Some mobile applications help reduce traffic congestion in the United States, and may serve as a cost-effective method to minimize Chinese traffic. If a Smart City adopts mobile applications with traffic management functions, city officials can encourage mass participation to effectively reduce traffic congestion, increase safety, and lower pollution. Mobile applications from the United States with these functions gather information by collecting data from personal phones and monitoring cameras and sensors. Major Chinese cities can develop mobile applications as a partial solution to their traffic congestion.

Users rate mobile applications with traffic management functions from the United States highly for their functions and usability. These applications determine the fastest routes with the least amount of traffic, search for parking locations, monitor traffic flow, and help find parking for the lowest cost. They aim to decrease driving time, and improve efficiency on the roads. China currently has mobile traffic applications, but their functions are limited. Other limitations include legal obstructions, development costs, and pressure from both international and domestic organizations.

Our project researches mobile traffic applications in the United States and China, and proposes their functions as a partial solution to the Chinese traffic problem. Surveys conducted in the United States and China gauge public perception of traffic applications. The United States survey centers on how the public values traffic application functions and their effectiveness. The Chinese survey focuses on their use, desire, and feasibility. Comparisons and contrasts drawn from each application's function determine what caters best to China. The strengths from United States traffic applications potentially satisfy the high demands from unpopular functions in the Chinese applications. Chinese Smart Cities can subsequently design and adopt applications to their infrastructure to suit the traffic demands of their citizens.

2. Background

Traffic congestion critically hinders the efficiency of major cities around the world. China faces some of the world's heaviest traffic, which wastes time, money, and resources for individual commuters. This section describes the impact of traffic, and indicates previous attempts at reducing traffic congestion in China. We describe the use of mobile applications as a Smart City initiative that collects data from commuters to aid in reducing traffic congestion.

2.1 Traffic Congestion in China

Population growth strains major cities in China and pushes the limits of their functioning capacities. If city officials improperly manage their resources and fail to adapt to urban growth, it leads to inefficiency, unnecessary expenses, and environmental issues. Traffic congestion causes severe waste of time, money, fuel, and road space. In 2015, traffic congestion cost Beijing 70 billion yuan (~10 billion USD) from idle vehicles wasting fuel (Custer, 2016). Traffic congestion also creates pollutants harming the urban environment and citizens' well-being. Many Chinese cities' infrastructure fail to accommodate their millions of inhabitants. Their highways are under constant construction and experience severe congestion (Custer, 2016).

China has 10 of the world's 30 most congested cities, each receiving a minimum congestion level of 35%. Traffic congestion level is measured by calculating the average time lost from a "free flow" road environment during an average commute. The result produces a congestion level, indicating the amount of extra time commuters encounter in the city (TomTom, 2015). Chinese drivers oftentimes take the same routes when commuting and cause traffic congestion by failing to avoid accidents and construction sites. Additionally, the number of cars in China continues to increase. In 2001, China produced approximately 1.9 million cars, increasing to 23 million cars in 2015 (Jones, 2011). Lastly, China's drivers are taught on closed roads as opposed to driving around other cars, causing accidents due to lack of practice in urban environments (Custer, 2016).

2.2 China's Response to Traffic Congestion

The number of Chinese roads, bridges, airports, railways, and new technologies expand to keep up with urbanization. China's 12th Five Year Plan increased the total highway span in China from 41,000 km (~25,000 miles) to 74,000 km (~46,000 miles) (World Highways, 2011). This includes the construction of seven mega-highways and nine expressways. The highway expansion caters to the increased car usage, and aims to decrease total traffic congestion.

China possesses one of the most advanced long-distance railway systems in the world. In 2011, the railway track expanded to 120,000 km, with 16,000 km being high-speed tracks. The total track distance surpasses the distance of every countries' railway systems combined (Sun, 2012). Despite this impressive expansion, the maintenance and operation of this infrastructure induces a strain on cities' economy and environment.

China continually goes over budget when building its major construction projects. In 2014, these projects cost approximately 65.1 trillion yuan (~9.4 trillion USD), the equivalent of one-third of the Chinese national debt (Browne, 2016). Between 2000 and 2014, nine out of ten of their major railway projects went over budget (McCrae, 2016). Andrew Browne states in his article about Chinese city infrastructure, "Simply put, Chinese city planning and improvements are inefficient and wasteful."

Besides large-scale expansion efforts, Chinese Smart City initiatives explore cost-effective solutions to improve traffic congestion. In the city of Jilin, a small-scale computer simulation utilizes GPS data from 200 buses and eight different routes. This simulation collects data from traffic light sequences, number of cars, and road signs from ten intersections. This compares traffic speed with the different traffic light sequences providing the most efficient traffic flow (Hornyak, 2015). TEB Technology Development Company proposed another initiative of a 1,200 passenger "straddling bus" in 2010. This bus is supported by tracks on both sides of the road, and reduces traffic congestion by deliberately driving above cars (Feng, 2016). Figure 1 below shows a working concept model of the bus.

Figure 1: A model prototype of the "straddling bus" concept (Ylanan, 2016)

China encourages the use of other modes of transportation to reduce traffic congestion. As of 2015, more than 17 Chinese cities use bus transit systems to connect subway stations to points of interest (Sun, 2012). To encourage bus use, some cities lower or temporarily remove bus transit fees on certain busy times, such as national holidays (World Bank, 2012). Chinese commuters also use subways as one of their most popular methods of public transportation. Chinese subway systems decrease pollution and effectively avoid roadway traffic. Lastly, many Chinese cities encourage personal and public bicycle use. For example, Hangzhou's bike sharing program attracts up to five riders per bicycle each day (Liu, 2011). Figure 2 depicts one of the city's many stations where users can rent and return bicycles. Many Chinese cities also develop designated bicycle lanes on roads, such as Figure 3, and expanded sidewalks for moped parking.

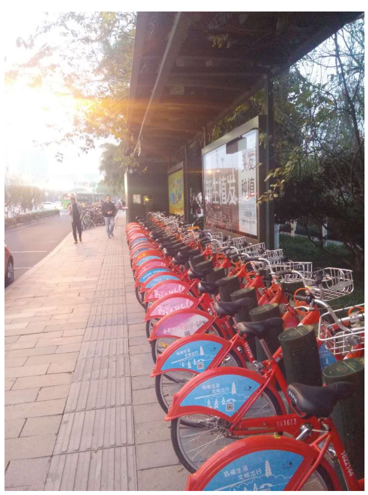

Figure 2: One of Hangzhou's bicycle sharing stations

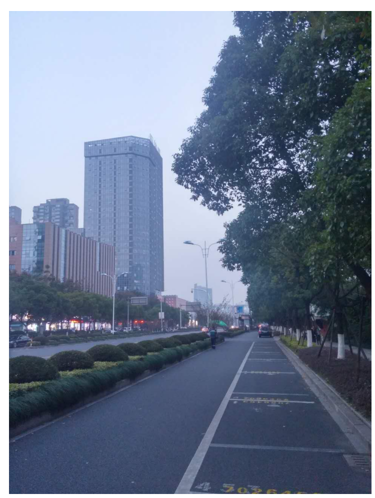

Figure 3: A lane designated for moped and bicycle use in Hangzhou

The Chinese government also incorporates regulations to help solve their traffic problem. In 2008, Beijing introduced the "Odd-Even Rule" to ration road-space in preparation for the Summer Olympics. This law restricted vehicle use on certain days depending on the last number of a car's license plate to improve air quality and lessen traffic congestion (Jin, 2013). Another regulation limits the number of car registrations during a given year, decreasing the amount of cars on the road (Sun, 2012). Beijing also adopted a congestion fee for travelers based on which district they drive through. The fee depends on the air pollution and traffic congestion levels (Sun, 2012).

2.3 Smart Cities, Mobile Phones, and the Reach of Mobile Applications

Smart City initiatives embrace technology to improve human life with minimum resource consumption. Smart Cities around the world implement technology into infrastructure to tackle traffic congestion. They utilize collected data to create solutions that improve city efficiency. From ecological monitoring to traffic management systems, Smart Cities adapt technology to increase process improvement. The cooperation between Smart Cities and their societies creates opportunities for wide reaching public input to the city's well-being.

Today, the convenience of data and information presents itself at the touch of a finger. Smart phones constantly collect data on individuals through location services, user input, and application ratings. The United States has 207.1 million smartphone users, expecting to rise to 222.9 million in 2017 (Cottini, 2016). China has 563.1 million smartphone users, expecting to grow to 601.8 million in 2017 (Cecilia, 2016). Naturally, the thought to include personal mobile applications in Smart Cities arises. Including smartphone applications in Smart Cities increases data collection speed and efficiency.

The 207.1 million smartphone users in the United States have a potential for Smart City initiatives to exploit mobile applications for data collection. Some mobile applications focus on traffic management methods to improve traffic congestion. These applications can benefit both the individual and the Smart City.

Popular mobile applications with traffic management functions exist in China. Some of these applications include Baidu Maps, Navmii:China, and Tencent Maps. These applications make users aware of traffic congestion. Applications exist in the United States similar to the aforementioned Chinese applications, including Google Maps, Apple Maps, and Sigalert. Other mobile applications, such as Waze, display accidents and road hazards. Some of the United States applications are nonexclusive, and make efforts to expand outside of the country.

2.4 Mobile Application Expansion Efforts

Mobile applications need user support to gain profit and increase application accuracy. Due to this, many applications make efforts to expand out of their countries of origin. In 2011, Waze acquired 30 million USD for a proposed expansion plan for China (Kim, 2011). Noam Bardin, CEO of Waze, stated in an interview "We think we have traffic here but when you get to China, you see what real traffic is. This is a strategic country for us. With the rate of growth and change in the infrastructure in China, traditional mapping technology has a hard time keeping up" (Kim, 2011). This expansion debuted in Beijing, but experienced a lack of initial user support required for the application to function effectively. Waze relies on crowdsourcing to accurately inform users of traffic conditions, and it suffers without user support. Waze ultimately did not gain full traction in China, as the focus of the expansion centered on popularity, not the functionality.

In the summer of 2015, Waze conducted a "MegaMapRaid". This split China into 12 regions, as shown in Figure 4, to map Chinese roadways in an effort to increase user support. The company formed groups of participants to fully map out China and market Waze as a traffic management application. The results of this expansion are undergoing evaluation by Waze and will be made public in 2017 (Waze, 2015).

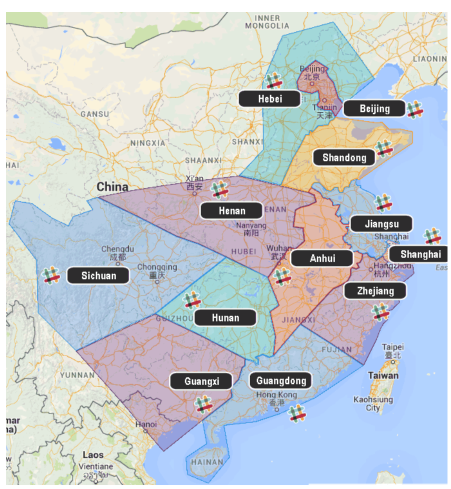

Figure 4: Waze 2015 MegaMapRaid regions (Waze, 2015)

2.5 Smart City Traffic Management and Regulations

Smart Cities also gather information from large-scale traffic-monitoring methods. These methods include live surveillance, congestion road maps, and traffic light sensors throughout the city (ClusterTech, 2015). Traffic officials throughout China utilize advanced technological applications to monitor traffic conditions in real-time. These applications allow traffic officials to use technology to reduce traffic light times and automatically relay traffic information to news and public channels.

These applications are solely maintained and operated at a governmental level, so the citizens do not have access to this information. While these applications offer partial solutions to traffic congestion issues, the lack of citizen knowledge and involvement in these applications decreases access to useful data. Government applications are limited to information gathered from installments on roadways and traffic management centers. Public involvement increases the amount of collected data to improve the efficiency of traffic management.

Chinese traffic regulations place significant constraints on drivers. One regulation impacting traffic management applications restricts sourcing on map services. There are two types of map sourcing: Open source and proprietary. Open source mapping allows for input from the public, government, and application developers. Proprietary mapping allows the application developers sole control over map creation and maintenance (Jacobs, 2014).

Chinese regulations dictate that mapping services and applications identify their sourcing as either open source or work collaboratively with the government (Ministry of Transport, 2015). Applications do not receive sole access to mapping criteria, and are required to follow specified guidelines outlined by the Ministry of Transport for the People's Republic of China (Ministry of Transport, 2015). These regulations constrain application developers to follow strict directives, limiting public input and profit gained from the application developers. Chinese regulation prohibits the use of mobile phones while driving (Ministry of Transport, 2015). However, cellular phones used as navigation systems are an exception. This allows the use of mobile applications with traffic management functions while driving.

3. Methodology

The goal of our project is to determine the impact of mobile traffic management applications on reducing traffic congestion, and to provide recommendations to the Zhejiang Smart City Research Center based on our findings. We used a combination of archival research and participatory methods to gather data on traffic conditions in both the United States and China. We conducted two surveys, one in the United States, and one in China.

3.1 Research Goal

We aim to determine the feasibility of applying traffic management functions of mobile applications from the United States to Chinese Smart Cities. We arrive at a conclusion and suggest recommendations based on background research and surveys issued in the Unites States and China. We divide our goal into the following research objectives.

3.2 Determine Four Functions of United States Mobile Traffic Management Applications

We conduct technical background research on popular traffic management applications in the United States and create a list of their functions. We investigate frequently occurring traffic management functions, and choose the four most common. We choose four traffic management applications correlating with the four selected functions using the highest rating average across four application stores.

3.3 Investigate Mobile Traffic Management Application Opinion in the United States

We create a survey for the United States public to determine their commuting habits, possession, and opinion of each chosen application function. Commuting habits include primary modes of transportation, time spent commuting, and distance travelled when commuting. We capture public opinion of the chosen applications through four generalized attributes: usability, affordability, effectiveness, and reliability. These attributes are rated on a 1-5 scale, with 5 representing the highest of each category. Our questions aim to understand how United States respondents experience traffic, and what they most and least value from mobile traffic applications. We graph the responses and compare the results with those of the Chinese survey.

3.4 Determine Four Functions of Chinese Mobile Traffic Management Applications

We determine common traffic management functions in mobile applications from China. We conduct technical background research on popular Chinese traffic applications, and choose the four most common traffic management functions. We choose four applications correlating with the four chosen functions using the highest rating average across four application stores. We compare these applications with the chosen applications from the United States.

3.5 Investigate Mobile Traffic Management Application Use in China

We create a survey for the Chinese public to understand their commuting habits and use of applications with functions similar to those of the chosen United States applications. Commuting habits include primary modes of transportation, time spent commuting, and distance travelled when commuting. If the respondents do not have at least one traffic application, we inquire their awareness and desire for each application function. Our questions determine how Chinese respondents experience traffic and their opinion on traffic applications. We graph the responses and compare the results with those of the United States survey.

4. Results and Analysis

This section provides an in-depth description of our findings and analysis. We begin by introducing our results framework, which includes pertinent information regarding the structure of the survey questions. We provide data gathered from our background research and survey questions. We compare the United States and Chinese survey responses to outline major findings.

4.1 Results Framework

Our results fall into two groups: information from selected mobile applications, and survey results from the United States and China. Research into both countries' mobile applications compares their traffic management functions. We investigated the following application stores from the United States for data on each application: Apple Store, Microsoft Store, Amazon Store, and Google Play. For the Chinese applications, we investigated the following application stores: Tencent App Gem, Baidu App Store, Apple App Store China, and Huawei App Store.

The survey data include user opinion on each application's functions and attributes. Each survey concentrates on two topics: exploring the current traffic situation in each country, and determining the public opinion of each traffic application's function. The first concentration asks commuters questions about their commuting habits. This includes primary mode of transportation, frequency of commuting, and time spent commuting. This first concentration validates the need of traffic management applications. The second concentration varies between the United States and Chinese surveys.

The second concentration of the United States survey explores the possession and opinion for each chosen traffic management application. Our survey asks if respondents have mobile devices that can download mobile applications. If they do not, then the survey ends. Our survey asks if the respondents know about the chosen United States applications. This provides a general gauge of popularity for each application. It inquires if the respondents have any of the four chosen United States applications. If they do, then the survey asks respondents of their opinion about each application.

We quantify this opinion by focusing on four attributes: usability, affordability, effectiveness, and reliability. These attributes best represent the user experience with mobile applications. Usability describes how user-friendly each application is. Affordability describes the magnitude of cost that users need to pay for the application services. Effectiveness describes the success of the application's intended functions. Reliability describes how little the application experiences software malfunctions.

We quantify each of these attributes on a 1-5 rating scale. For each attribute, a score of 5 represents the highest satisfaction. The survey concludes by asking respondents to list additional functions they deem most helpful, and functions that require improvements in these applications. By determining the user opinion on each application from the United States, we predict the outcomes of expanding the application functions in China.

The second concentration of the Chinese survey explores interest in implementing each of the chosen United States applications' functions. Our survey inquires if the respondents can download mobile applications. If they cannot, then the survey ends. Our survey asks the respondents if they possess applications with functions similar to the United States applications. If not, our survey asks if the respondents are aware of mobile applications with these functions and if they desire these functions. We base the feasibility of bringing the United States application functions to China off of these questions.

4.2 United States Mobile Application Results

The traffic management functions of the chosen applications from the United States are traffic congestion display, hazard reporting, parking availability, and nearby parking prices (Table B1). Traffic congestion display and hazard reporting inform users of traffic congestion and road hazards to provide users the opportunity to take alternate routes. Parking availability and parking pricing inform users of available parking locations and the prices of parking to decrease time and resources wasted searching for them. We considered each application's General Rating Index (GRI), as a weighted average of each application's rating across four chosen application store platforms (Table B2). We calculate an application's GRI as a score between 0 and 5, to determine preliminary public opinion. Closer GRI's to 5 represent more pertinent applications to represent our traffic management functions. We also conducted background research into each application to determine possible feasibility of each application's function in China.

The following applications have the highest GRIs of the investigated traffic management functions. Sigalert exhibits the traffic congestion display function with a GRI of 3.26. Waze exhibits the hazard reporting function with a GRI of 4.59. Parker exhibits the parking availability function with a GRI of 3.32. BestParking exhibits parking the price function with a GRI of 4.56. These scores do not take into account voluntary response bias, possible cultural bias, or paid rating services.

Waze serves as a traffic management application with a GPS navigation tool and warning system for obstructions in traffic flow. This application operates in 60 countries and plans to expand to China (Waze, 2016). Waze updates its maps continuously through user input, and informs users of major traffic congestion, roadblocks, police locations, and gas prices. iTunes, Amazon Apps, Microsoft store, and Google Play all offer the application. Waze functions on the premise that the public continually monitors and updates its live maps. Waze produces numerous updates to keep the application effective and is received well by the community. This resulted in over 5.23 million total reviews and over 7 million users through Waze's lifetime (Waze, 2016).

Founded in 1998, Sigalert began as a radio traffic reporting service, and now fully serves as a functioning traffic mobile application. It partners with Total Traffic Network to utilize thousands of traffic cameras across the nation and provides live imagery of the congestion of user-specific roadways. These cameras cover 350,000 miles of road, reaching 75 major metropolitan areas exclusively in the United States (Sigalert, 2016). The application also creates a live, interactive color-coded map that shows the traffic congestion of local roads. For these roads, the average speed of cars display as well. The application is free for viewing cameras, but paid memberships grant access to additional features. Members can create a personal route and receive daily notifications on traffic hazards. These features save time, fuel, and roadway stress.

Parker displays real-time parking lot availability in over 24,000 locations in thirty cities in the United States and the United Kingdom (Streetline, 2016). Sensors installed in garages and lots detect vehicles and relay available parking to the application. Streetline, the application's owner, names their methodology "Smart Parking" due to its users having instant access to their information. Smart Parking saves time, distance driven, gallons of gasoline, and pollution (Streetline, 2016). Parker's popularity originates from businesses installing sensors to attract customers who want the assurance of finding parking spots.

BestParking is an application that steers users to the cheapest and most convenient parking spaces. Users can search for parking facilities by attraction, neighborhood, address or road intersections, and compare pricing. BestParking serves 105 cities and 115 airports; its 850,000 monthly users can access 12,000 parking facilities (BestParking, 2016). Users can also make reservations at the majority of these airports. This application allows users to access rates and the details of each facility. These details include vehicle height allowance, surcharges and information phone numbers.

4.3 Chinese Mobile Application Results

Several Chinese mobile applications focus on traffic management methods to combat congestion. Mobile applications, such as Tencent Maps (also known as QQ Maps), Navmii: China, Baidu Maps, and Ubo aim to reduce traffic congestion by gathering data from their users.

Tencent Maps is similar to Google Maps. Users can lookup nearby restaurants, gas stations, attractions, and ATMs. This application is well received among the Chinese community, and incorporates a sophisticated traffic management system and street view database (Millward, 2014). The application server collects data from its users, making its function possible to serve as a Smart City initiative to reduce traffic congestion.

Navmii: China guides drivers to their destinations via GPS navigation. Additional features include comprehensive data on user history, average speed, etc. This application also features the ability to share traffic route information with other users (Navmii, 2016). Navmii: China focuses software updates on fixing glitches instead of renewing maps. Due to this, users report that the application loses functionality, and therefore fails as a navigation system (Navmii, 2016).

Baidu Maps orients and guides users as a web-mapping GPS application. Users can access the application via computer or mobile phone. A small variety of countries support the application, but is only offered in Mandarin (Baidu, 2016). The application's server gathers traffic data and displays it to the users, making its function a viable candidate as a Smart City initiative to reduce traffic congestion.

Ubo exists solely in Beijing, China as a valet parking application. It offers users the chance to reserve valet spots in congested city areas for efficient parking. It has a small number of users despite being offered on a number of application stores (Shu, 2015). The lack of popularity and function reduce this application's potential influence on traffic management in China. However, the base function of this application serves to reduce traffic congestion by informing users of their parking locations in advance.

The chosen Chinese applications have similar traffic management functions to the United States' applications (Table C1). Due to limited rating information available on the Chinese application stores, we are not capable of calculating the GRI. Instead, we look at the functions present within each application as the determining factor. Tencent Maps and Baidu Maps exhibit the traffic congestion display function. Navmii: China exhibits the hazard reporting function. Ubo exhibits the parking location and pricing functions.

4.4 United States Survey Results

Our United States survey (Appendix D), distributed through Google Forms, received 303 responses between November 18th 2016 and December 10th 2016. Our survey received responses from 19 states. This data spread is depicted in Figure 5 below. This survey contains questions about commuting patterns, time spent in traffic, distance traveled on a daily basis, and the mobile applications: BestParking, Waze, Sigalert, and Parker. Appendix F has the full listing of data and respective graphs from the United States survey.

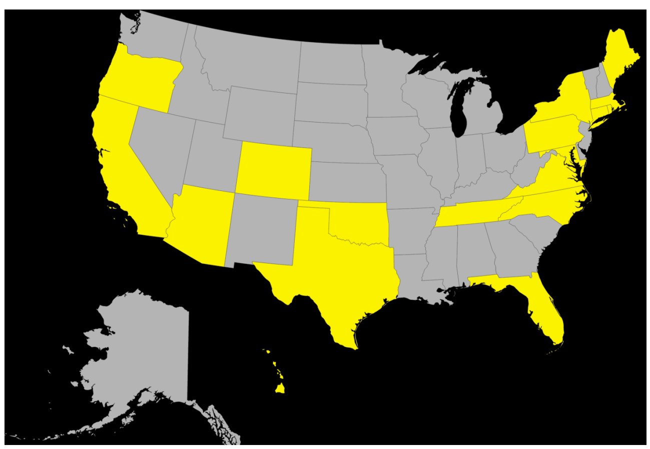

Figure 5: United States survey respondent locations

77.5% of respondents use personal cars as their primary mode of transportation (Figure F1). A majority of respondents commute 0-20 miles (Figure F3), and spend 0-60 minutes commuting (Figure F9). 84% of respondents spend less than 30 minutes in traffic (Figure F11).

The majority of those surveyed has a mobile application that shows nearby traffic congestion, but do not have a parking application. 58.4% of respondents have heard of Waze before, and 48.7% of those individuals owned the application (Figure F6 and Figure F7). Unlike Waze, few respondents use Parker and Sigalert, and no respondents use BestParking.

The United States survey also asks respondents to provide the most and least helpful features if they use the chosen traffic mobile applications. The majority of respondents used Waze and mentioned that it functions efficiently when traveling to busy cities as seen in Figure 6. However, the application suffers from technical issues and unfavorable updates according to the respondents as seen in Figure 7. Sigalert had one answer to the most and least helpful features, making the response negligible. Parker and BestParking did not receive any comments.

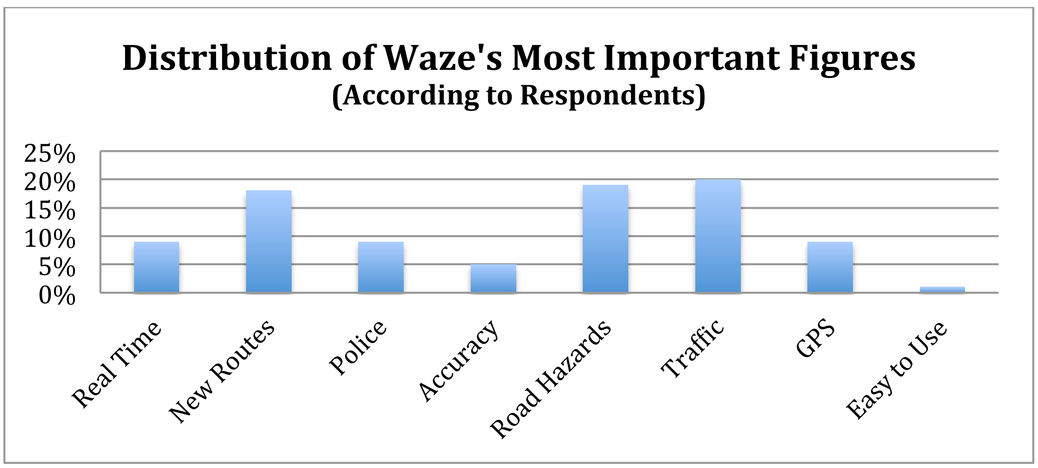

Figure 6: Waze most important features survey responses

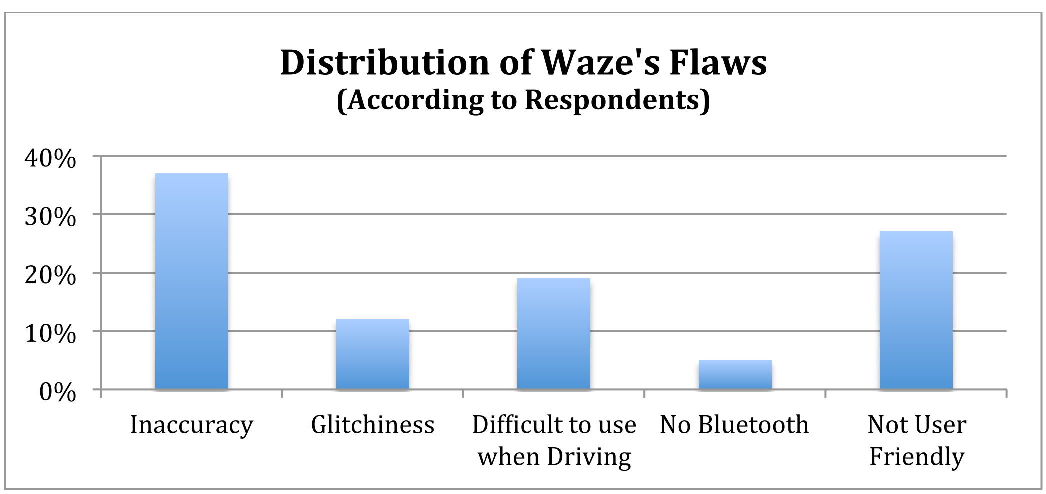

Figure 7: Waze least important features survey responses

4.5 Chinese Survey Results

The questionnaire website, Sojump, hosted the 19-question Chinese survey after translation to simplified Chinese. The survey's questions inquire about the current Chinese traffic and available mobile traffic management applications. We distributed the survey link using WeChat, and emailed it to connections throughout China. This survey generated 158 responses across 14 provinces, 3 municipalities, two autonomous regions, and Macau. The data spread is depicted below in Figure 8. This survey also contains two categories of questions based on the respondents' commuting habits and mobile applications.

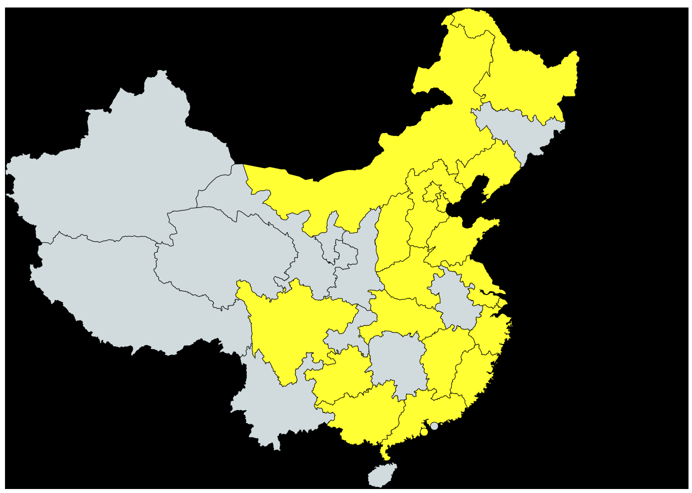

Figure 8: China survey respondent locations

28.48% of respondents commute primarily using a private car, while 56.96% commute using public transportation (Figure F1). 25.32% of respondents commute daily, and 79.75% of those take the same route when commuting (Figure F2 and F3). 41.14% of commuters spend 0-30 minutes commuting. 36.71% of respondents spend 30-60 minutes commuting, and 75.95% travel 0 – 10 kilometers a day (Figure F10 and Figure F11).

81.01% of the respondents use smartphones with the capability of downloading applications (Figure F5). However, most Chinese smartphone users lacked traffic applications similar to those of the selected United States applications. 59.38% of the surveyed own an application that displays traffic congestion. Meanwhile, 14% own a parking availability application (Figure F7). 33.59% of respondents own hazard reporting applications, and 16.41% of respondents own parking price applications (Figure F7).

The Chinese smartphone users without traffic applications mostly lacked awareness about applications with traffic management functions. 4.67% of the respondents knew about of a parking price application. 13.46% of respondents knew about a traffic congestion application (Figure F7). 10.59% of respondents knew of available hazard reporting applications, and 14% of respondents knew of available parking availability applications.

The second concentration of the survey asks about the desire of the United States functions in traffic management applications. 76% of respondents considered downloading a parking availability application, making it the most popular function. 71.76% of the surveyed considered downloading an hazard reporting application. 71.15% of respondents were interested in a traffic congestion application, and 70.09% of respondents were interested in parking price applications (Figure F7).

4.6 Comparing United States and Chinese Surveys

Most Chinese respondents utilize public transport as their primary mode of transportation followed by private cars. In contrast, the United States respondents utilize personal cars as their primary mode of transportation, followed by public transportation. This shows that most Chinese commuters contribute to, and are affected by traffic congestion. Most Chinese daily commuters spend 0-30 minutes of their time when commuting 0-10 kilometers (0 – 6.2 miles). However, a significant percentage of Chinese commuters spend 30-60 minutes commuting as well. The majority of United States respondents also spend 0-30 minutes commuting. However, 49% travel between 0-10 miles (0-16.1 km). The graphs below provide a visual representation comparing the United States and Chinese travelling conditions.

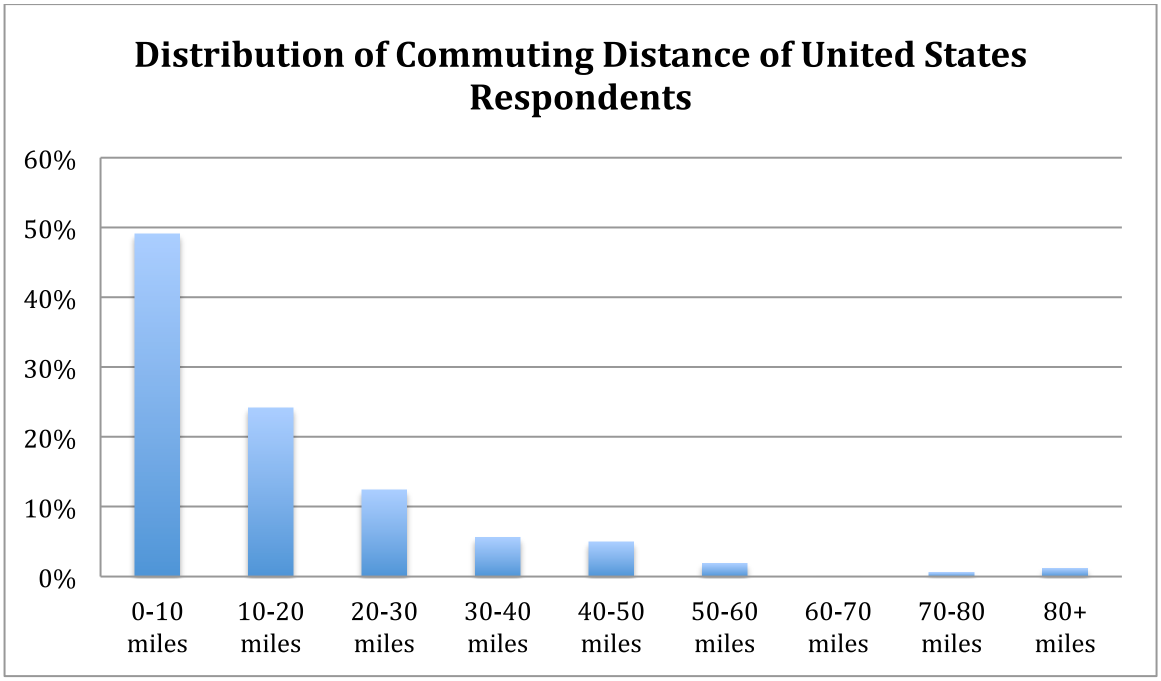

Figure 9: United States commuting distance

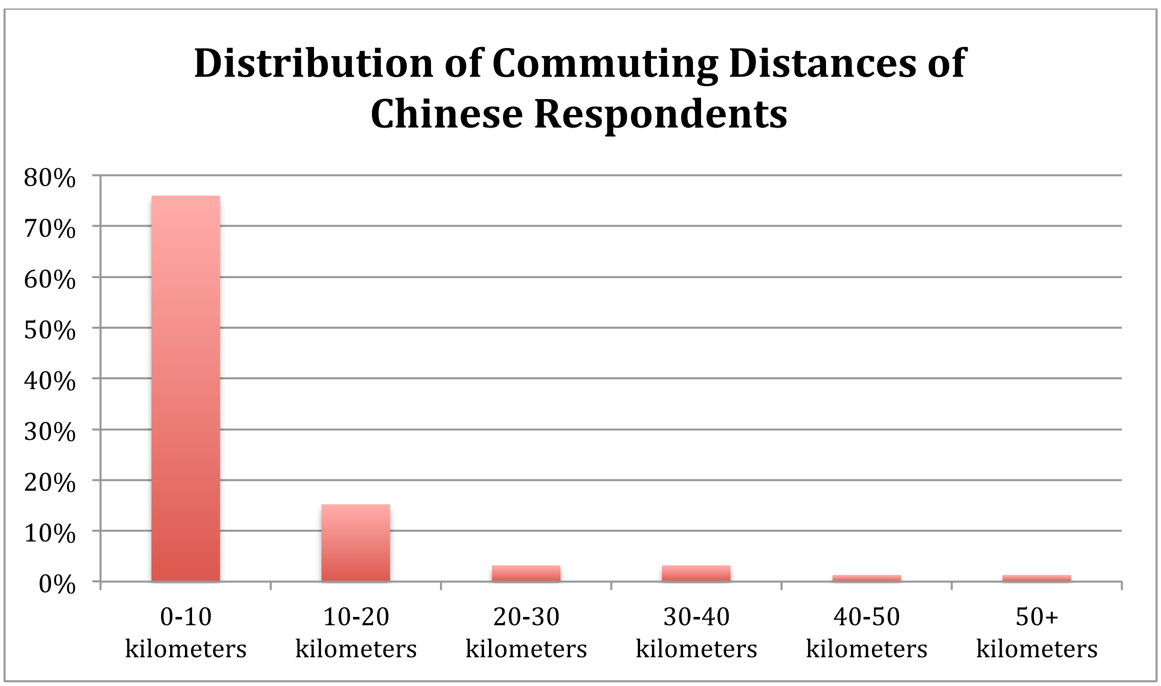

Figure 10: Chinese commuting distance

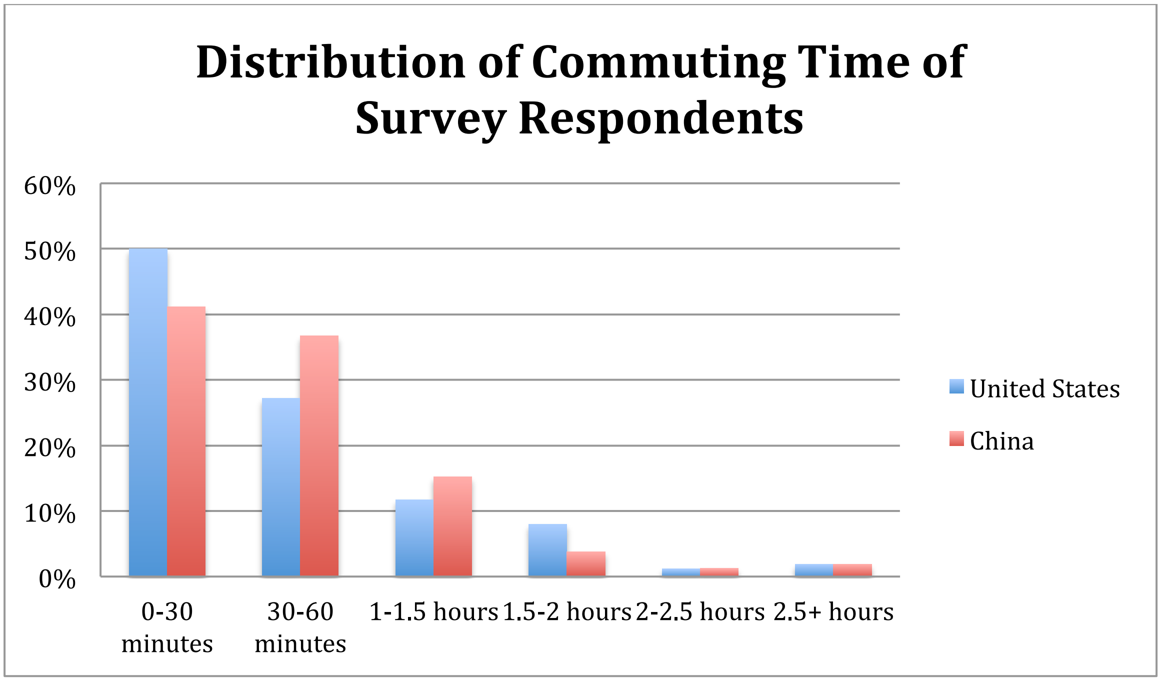

Figure 11: United States and Chinese commuting time

The figures above indicate the staggering difference between United States and Chinese commutes. Figure 10 illustrates that a vast majority of Chinese commuters travel a short distance. In contrast, Figure 9 shows that the United States respondents commute a wider range. Comparing this with Figure 11 reveals that Chinese commuters spend a longer time travelling shorter distances than United States commuters. We conclude that higher traffic congestion in China compared to the United States causes these trends.

Many factors influence why traffic congestion in China is higher than in the United States. As discussed in the background section, the number of Chinese vehicles, available routes, and congestion-heavy roads factor into their traffic. The widespread use of private vehicles provides a medium to reduce traffic congestion.

Most of the respondents with Chinese smartphones lack traffic applications. From that majority, most users do not own one due to lack of awareness of such applications. However, those without traffic applications expressed interest in downloading one. The Chinese respondents who do own traffic management applications primarily had ones displaying traffic congestion.

The data indicate Waze as the most popular application in the study and had high ratings for affordability and reliability. This application also contains the most features compared to the other United States applications (Table B1). However, from our background research, some features, such as police reporting and crowd sourcing will not work as well in China. The regulations in China prohibit or limit these features, concluding that the traffic management function hazard reporting must alter before coming to China.

The other traffic management functions that need alterations before coming to China are parking availability and parking prices. In both of these cases, the functions were poorly known in the United States. This shows the necessity for improved marketing. As for the few respondents who had these applications, the applications were rated poorly in usability. This indicates the need to make it easier to use. Despite the low awareness of these applications in the United States, the Chinese surveys indicate that commuters desire these traffic management functions the most. We found that Chinese respondents care more for the assurance of parking spots than for the commute. In conclusion, we found the United States and Chinese surveys reflect similar interests in efficient traffic management applications.

4.7 Survey Limitations

The United States survey received 303 responses. This creates less accuracy where possible trends minimize due to outliers. Additionally, the extent of our personal connections results in most responses originating from our respective hometowns and Worcester Polytechnic Institute in the United States. We encounter the same challenge in China, as our connections limit to students of Hangzhou Dianzi University and our sponsor. We minimize this location bias by encouraging the respondents to spread the survey to other individuals and groups to collect further data.

The format of the survey questions in the United States causes another limitation. In this survey, if respondents answered “No” to commuting every day, then the survey would end. This limits the total number of responses for further questions. The United States responses were cut from 303 responses to 161 in some cases. Numerous questions contain this format, so the responses form bias on those individuals that commute everyday or have the ability to download mobile applications.

Voluntary response bias, or the desire or lack thereof for individuals to take the survey, limit the amount of responses from both countries. Those who hold stronger opinions, or have experience with mobile traffic applications have higher chances of taking the survey. This limits the responses to highly opinionated biases, neglecting the average experience. We minimize this potential bias by distributing the surveys to as many individuals as possible at varying age ranges for both the United States and China

Information from mobile application websites is possibly inaccurate. Their online ratings from the application stores, as outlined in the background section, may have voluntary response bias. This can cause considerably high or low ratings if the respondents have incentives (in-app deals, rewards, etc.) or particular user dissatisfaction. To minimize voluntary response bias from application stores, individuals in both surveys rated their own traffic applications if they had at least one.

4.8 Challenges of Applying Mobile Applications

The first major challenge with this research involves the cost of bringing the functions of United States applications to China. Mapping cities, maintaining these functions, and incorporating city installments in applications requires high costs. Additionally, the creation of a new mobile application that encompasses these functions of traffic management costs a significant amount of money to the developer or user. To limit the cost that is experienced by the developers, funding can be provided in part by the government. This reduces some of the strain on the developers and users, and allows developers to continue working on updates for the improvement of the application.

The second limitation from recommending these application functions comes from regulating the implementation of these applications on the larger scale. Cooperation and collaboration with the government, specifically through the Traffic Management division, helps the developed application adhere to all legal regulations.

The third challenge involves the effectiveness of the applications. To further complement the functions the population desires, the application must be constantly updated and run through a large number of coders. This level of intensive work requires dedication and teams devoted to process improvement. A mobile phone provider or the government must sponsor or collaborate with Smart Cities to implement a successful application.

The research and results present in this research also face some levels of limitations and challenges. The survey findings from this report held a small response rate and may not accurately portray traffic situations and opinions of traffic applications in both countries. The

United States survey received 303 responses, and the Chinese survey received 158 responses, and they do not take underrepresented regions of the United States and China into account.

5. Conclusion and Recommendations

This section provides an overview of the impact of mobile applications on collecting data and reducing traffic congestion. Mobile applications provide an opportunity for Smart Cities to gather a consistent and measurable amount of data, which can be used to create solutions to Chinese urban projects. This data allows the cities to monitor commuting habits and alter traffic management methods for optimal traffic flow. We make two recommendations to the Zhejiang Smart City Research Center based on our findings. This section first outlines the findings and conclusions of specific application functions, and then provides detailed recommendations.

5.1 Unified Traffic Management Applications

China lacks a dominant provider in application map technology, leading to the creation of many smaller applications (Kim, 2011). Section 4.8 briefly describes the challenges these applications face. However, the complex issue in the creation of a traffic management application stems from challenges in application maintenance in China's competitive market.

Application developers do not have the access of preliminary means of traffic data management, and cannot produce a significant profit through the application. The lack of funding reduces the number of employees working on individual applications, and makes large-scale applications difficult to maintain. Some applications, such as Baidu Maps, cooperate with larger organizations and application providers to allow for continual improvement of the application. This cooperation allows for additional funding and marketing to increase popularity and functionality of these applications.

Effective traffic management requires an aware and responsive population adaptive to traffic in urban environments. Smart Cities rely on constant data gathering from multiple sources, especially the public. Chinese Smart City initiatives can greatly reduce traffic congestion if they gather large amounts of traffic information. Therefore, mobile applications serve a crucial role in collecting data and improving city efficiency.

5.2 Parking Application Findings and Conclusions

Parking applications contribute significantly to Smart Cities and reducing traffic congestion. These applications constantly collect data and relay this information to the application database. This data source is paramount in monitoring parking lot capacities, parking trends, and the necessity for additional parking locations. Mass participation in parking applications potentially reduces the time users spend looking for parking spots, leading to the reduction in traffic congestion.

We found that most Chinese and United States commuters do not possess parking traffic management applications.

The United States and Chinese surveys received low number responses to the possession of parking location and price applications. A higher number of Chinese respondents possessed these application functions compared to United States respondents.

We found that most Chinese commuters are not aware of parking traffic management applications.

The respondents who did not possess the parking traffic applications were asked if they were aware of these applications. The Chinese survey received limited responses to the awareness of parking applications.

We found that parking functions are highly desired in Chinese mobile traffic management applications.

The Chinese respondents who did not possess a parking traffic application were asked if they would desire a mobile application with parking functions. A large majority of these respondents express high desire for applications that display available parking locations and prices.

We conclude that parking application functions require improved marketing before successful implementation in China.

The two United States parking applications did not receive many reviews in our survey for their affordability, effectiveness, usability, and reliability (Appendix C). However, the application store reviews of Parker and BestParking are rated highly. The limited United States survey responses denote the need for significant improvements in marketing for these parking applications. These applications require higher user support to be successful.

5.3 Parking Application Recommendation

Our findings indicate that parking applications serve a crucial role in reducing traffic congestion. Additionally, we found that the majority of the Chinese population is unfamiliar with mobile applications with parking functions. These findings and conclusions lead us to develop our first recommendation to the Zhejiang Smart City Research Center.

We recommend the Zhejiang Smart City Research Center investigate and propose the development of a unified application to the Traffic Management division of the Chinese government.

The cooperation between the research center and the Chinese government provides the possibility to create a unified parking application. We propose the application contain both parking locations and parking price functions. This simplifies commuter choice in a parking application.

The government can provide partial funding to the research center to employ an application developer to help create this application. Government collaboration also limits accidental legal obstructions that those involved may encounter. The government may include traffic management installments, such as parking sensors to aid in the application's functions. Including sensors in parking lots notifies users of the available parking locations, and collect more data from the application database.

The Zhejiang Smart City Research Center can provide the government a comprehensive data source from the application's database. These data indicate the trends and availability of parking sources throughout China, in which the government can use to implement further parking initiatives. The research center also provides a method of marketing the unified application. Parking applications encounter lack of awareness and popularity as challenges. The research center and traffic management division of the Chinese government may cooperate to promote this application through various mediums. By providing advertisements on television, radio stations, and applications, popularity of this unified application can reach a larger audience, and further cement itself as the dominant parking application. A large user support will lead to high revenue from this application's advertisements. This creates the crucial funds necessary to maintain the application and pushes the application to become self-sufficient.

5.4 Traffic Congestion Display and Awareness Findings and Conclusions

Traffic congestion monitoring aids Smart Cities and traffic management as a valuable tool. Mobile applications with congestion monitoring functions collect ample data on traffic patterns and traffic flow. Mass participation in a mobile application with traffic monitoring functions serves as a potential initiative to reduce traffic congestion. Users of this application can avoid road hazards and take alternative routes to reduce time spent in traffic.

We found that Chinese and United States commuters desire traffic congestion display and hazard reporting applications.

The United States respondents displayed high interest in both traffic congestion display and hazard reporting applications. The Chinese respondents indicated the highest desire for these applications. However, the Chinese desire for both traffic monitoring applications were lower than their desire for parking application.

We found that most Chinese commuters are not aware of hazard reporting traffic management applications.

The majority of Chinese respondents that did not own an hazard reporting application were not aware of traffic congestion monitoring and traffic hazard reporting mobile applications. These respondents were more aware of these applications than the parking location and parking price applications. Despite this, many respondents were not aware of the traffic monitoring applications

We found that traffic monitoring functions are highly desired in Chinese mobile traffic management applications.

The Chinese respondents who did not possess a traffic monitoring application were asked if they would desire a mobile application with traffic monitoring functions. A large majority of these respondents express high desire for an application that display traffic congestion and hazard reporting. This indicates that among the commuting population in China, the desire for traffic monitoring applications is high.

We conclude that traffic monitoring application functions require improvements to services before successful implementation in China.

The two chosen United States traffic monitoring applications are successful in their functions. The respondents rate both Waze and Sigalert highly on their affordability, effectiveness, usability, and reliability. In both Waze and Sigalert, respondents indicated the most important attributes of these traffic monitoring applications are affordability and reliability. Commuters care most about the assurance of a reasonably priced application that is reliable to their respective functions. Both of these applications are rated highly in this, however the source of their functions needs to be altered. As mentioned in the background section, there are Chinese regulations that restrict the use of open source applications under specified guidelines. The government needs to have control over the sourcing of the application to provide further accuracy and functionality.

We conclude that traffic monitoring application functions require improved marketing before successful implementation in China.

Waze and Sigalert received high ratings on their application stores. However, the survey noted that approximately half of the respondents knew of these application functions. The Chinese responses on traffic monitoring applications, while higher than the parking functions, still did not receive a tremendous amount of user awareness. This indicates that the marketing of these applications requires improvement before successful implementation in China. Similar with the parking application, a highly advertised application increases the public's awareness and use of this application.

5.5 Traffic Congestion Display and Awareness Recommendations

Our findings indicate that traffic monitoring applications have the potential to reduce traffic congestion. Additionally to this conclusion, we found that the Chinese population is not aware of mobile applications with congestion display and hazard awareness functions. The implementation and marketing of a comprehensive traffic monitoring application can further aid in traffic reduction initiatives. These findings and conclusions lead us to develop our second recommendation to the Zhejiang Smart City Research Center.

We recommend the Zhejiang Smart City Research Center investigate and propose the development of a unified traffic monitoring application to the traffic management division of the Chinese government.

As mentioned in the parking application recommendation, efficient application development requires cooperation. Cooperation between the Zhejiang Smart City Research Center and the Chinese government is imperative for the development of a unified traffic monitoring application. We propose the application contain both traffic congestion display and hazard reporting functions.

The government can provide the partial funding of this unified application. In addition to the funding, the collaboration also limits accidental legal obstructions that the research center and application may encounter. With government oversight on the application functions and sourcing, the legal constraints will be maintained, and the application can operate with higher efficiency. The traffic management division of the government can use the collected data to map out commonly congested roads and the causes of such congestion. These data can reduce further congestion with the implementation of this unified application and governmental traffic management projects.

The Zhejiang Smart City Research Center can also provide a method of marketing the unified application. The research center and traffic management division of the Chinese government may cooperate to promote advertisements on television, radio stations, and applications. The demand and use of this unified traffic monitoring application increases with the accuracy and amount of data provided by the population.

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Appendix A (Sponsor Description)

The Zhejiang Smart City Research Center investigates the impacts of urbanization in the Zhejiang Province. This center devotes its research to the improvement of urban planning and Smart City projects. Our sponsor for this project is Dr. Lu Huang, who works in the research center. Her research focuses on the three dimensions of sustainability: economy, environment, and society. The three dimensions of sustainability are analyzed through the Gross Domestic Product (GDP), Genuine Progress Indicator (GPI), Ecological Footprint (EF), Biocapacity (BP), Environmental Performance Indicator (EPI), City Development Index (CDI), and Human Development Index (HDI). Dr. Huang has contributed to numerous research articles.

Appendix B (United States Applications, Functions, and Ratings)

B.1 Functions of United States Applications

Table B1: United States application functions

United States Application Functions	**Waze**	**Sigalert**	**BestParking**	**Parker**
GPS Navigation	x			x
Accident Alert	x			
Road Hazards	x			
Traffic Congestion	x	x		
Police Stops/Information	x			
Live Traffic Monitoring	x	x		
Traffic Camera Monitoring		x		
User Input to Traffic Conditions	x			
User Preferences	x	x	x	x
Parking Locations			x	x
Parking Prices			x	x
Parking Reservations			x	
Parking Availability				x

B.2 Application Ratings

Table B2: United States application ratings and downloads

United States	**Apple (all versions)**	**Amazon**	**Google Play**	**Microsoft Store**	**Weighted average or Total**
Sigalert	**2.0**	**3.8**	**3.8**	**X**	**3.26**
1 star	X	31	209	X	**240**
2 star	X	10	89	X	**99**
3 star	X	28	158	X	**186**
4 star	X	50	333	X	**383**
5 star	X	152	705	X	**857**
Total Downloads	X	X	100,000 – 500,000	X	
Total Number of Ratings/Reviews	850 (33.12%)	221 (8.61%)	1,494 (58.25%)	X	**2,565**
Parker	**3.5**	**X**	**3.2**	**X**	**3.32**
1 star	X	X	78	X	**78**
2 star	X	X	34	X	**34**
3 star	X	X	42	X	**42**
4 star	X	X	65	X	**65**
5 star	X	X	92	X	**92**
Total Downloads	X	X	50,000 – 100,000	X	
Total Number of Ratings/Reviews	214 (40.76%)	X	311 (59.23%)	X	**525**
Waze	**4.5**	**4.2**	**4.6**	**3.0**	**4.59**
1 star	X	198	121,413	1,681	**123,292**
2 star	X	78	78,548	453	**79,079**
3 star	X	128	252,950	544	**253,622**
4 star	X	386	1,170,777	704	**1,171,867**
5 star	X	1,621	3,897,234	1,596	**3,900,451**

Table B3: United States application ratings and downloads

Total Downloads	X	X	100,000,000 – 500,000,000	X	
Total number of ratings/Reviews	311,297 (5.33%)	2,025 (.0034%)	5,521,015 (94.55%)	4,978 (.0085%)	5,839,315
Best Parking	**4.5**	**x**	**4.6**	**X**	**4.56**
1 star	X	X	191	X	**191**
2 star	X		124	X	**124**
3 star	X	X	260	X	**260**
4 star	X	X	1,424	X	**1,424**
5 star	X	X	5,442	X	**5,442**
Total Downloads	X	X	500,000 – 1,000,000	X	
Totals number of ratings/reviews	5,671 (43.25%)	X	7,441 (56.75%)	X	**13,112**

B.3 United States Application Rating Graphs

B.3.1 Sigalert:

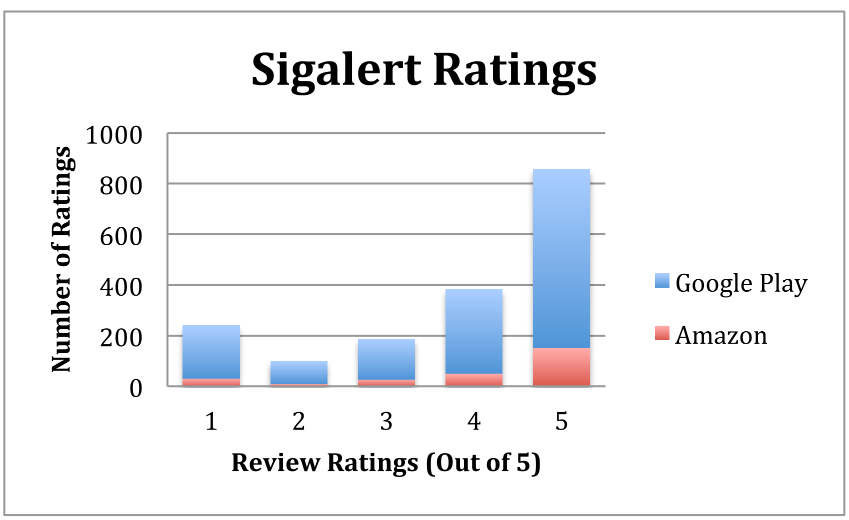

Figure B1: Available Sigalert ratings

B.3.2 Parker:

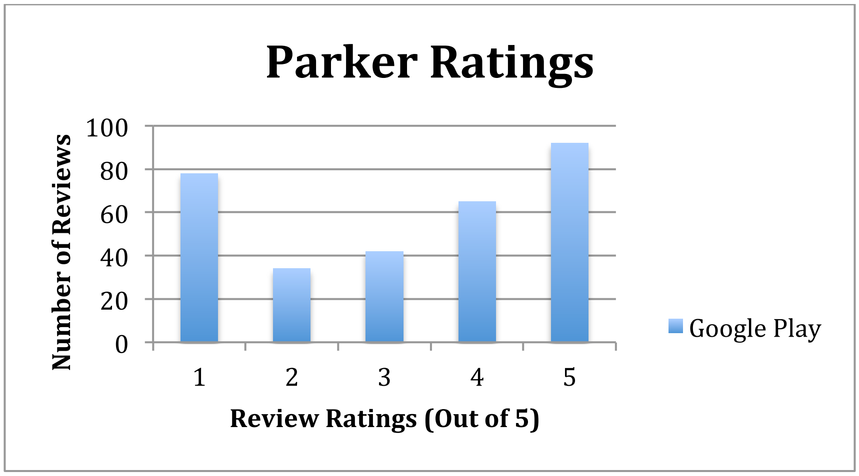

Figure B2: Available Parker ratings

B.3.3 Waze:

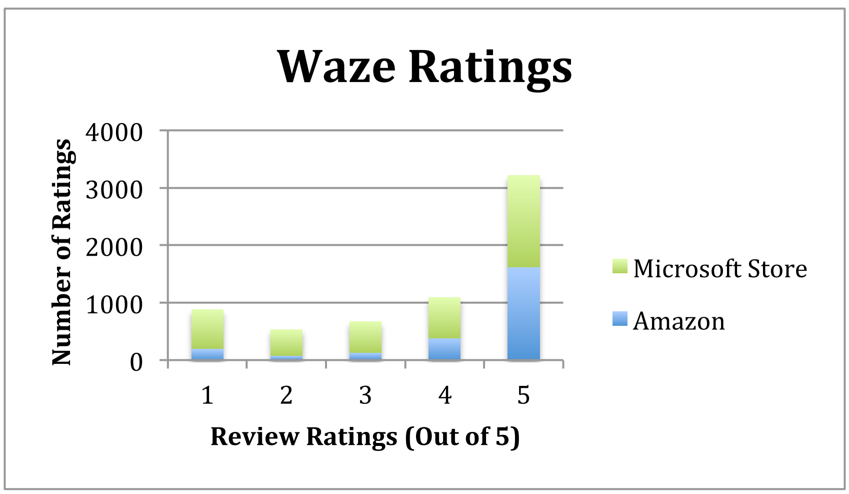

Figure B3: Available Waze ratings

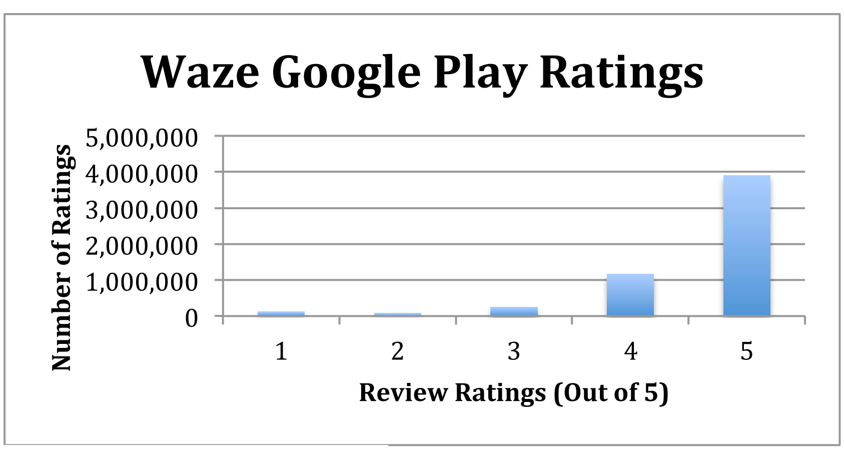

Figure B4: Available Waze ratings

B.3.4 BestParking:

Figure B5: BestParking available ratings

B.4 Averaged Bar Charts for Application Ratings

B.4.1 Sigalert:

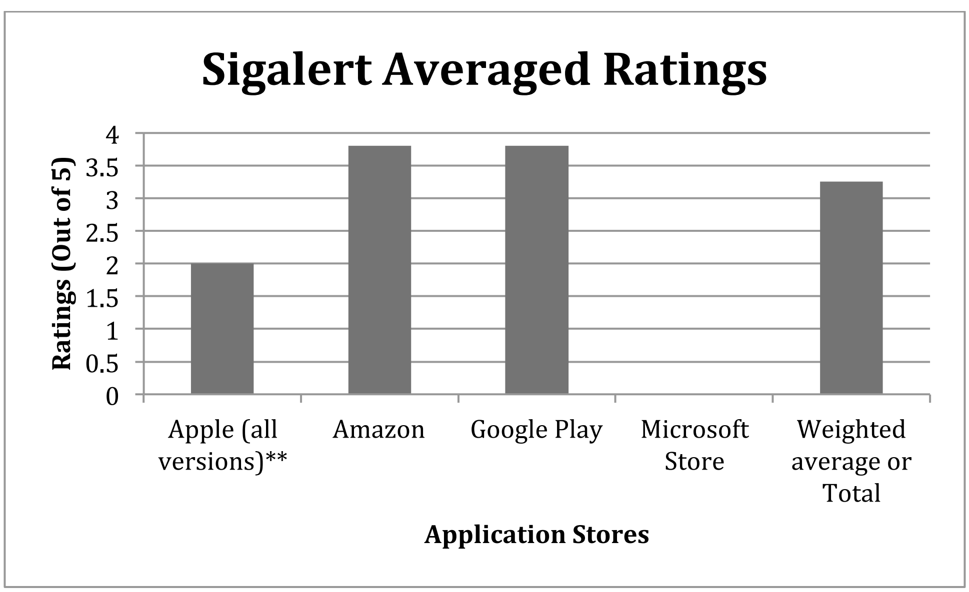

Figure B6: Sigalert averaged ratings for all application stores

B.4.2 Parker:

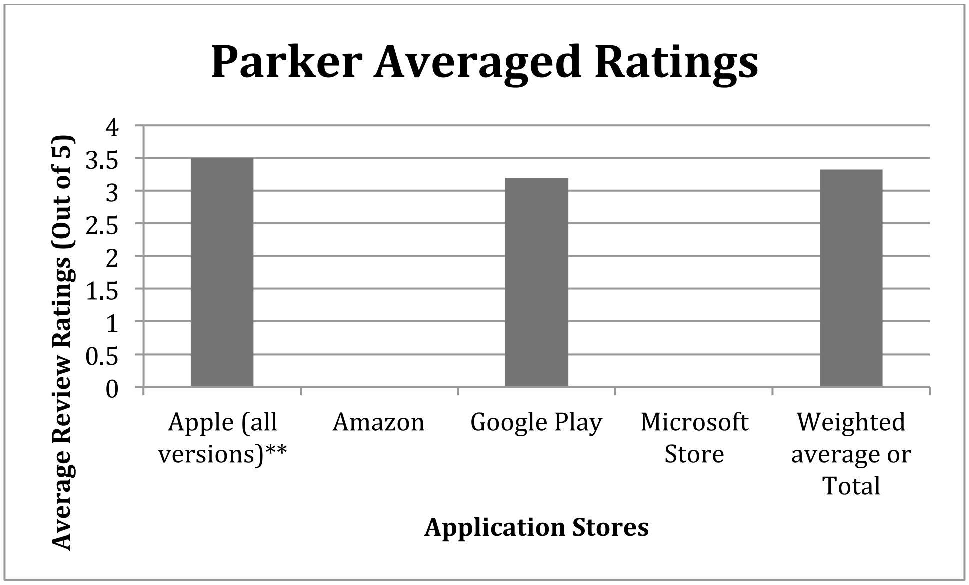

Figure B7: Parker averaged ratings for all application stores

B.4.3 Waze:

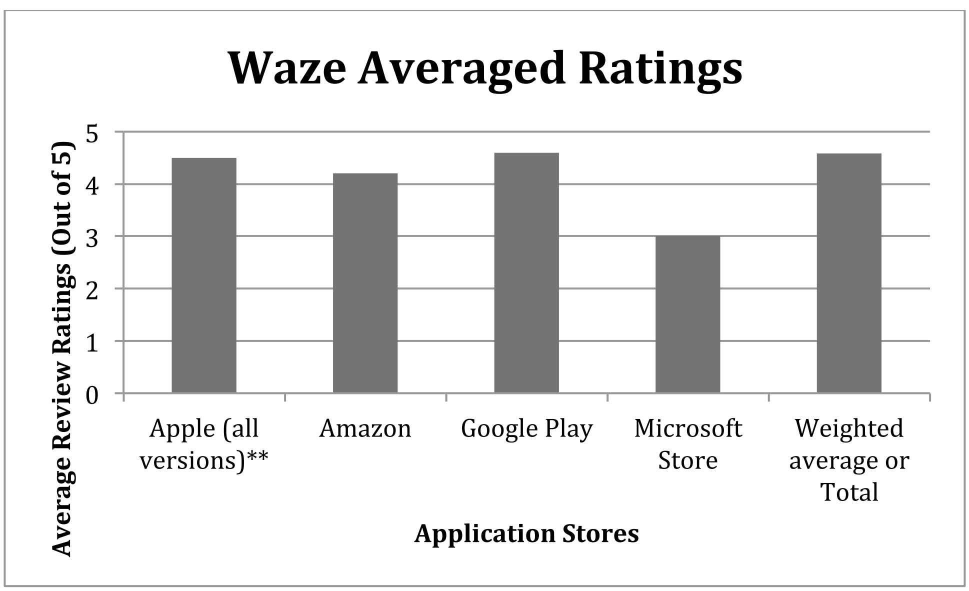

Figure B8: Waze averaged ratings for all application stores

B.4.4 BestParking:

Figure B9: BestParking averaged ratings for all application stores

Appendix C (Chinese Application Functions)

Table B3: Chinese application functions

<u>Chinese Application Functions</u>	Baidu Maps	Tencent Maps	Navmii: China	Ubo
GPS Navigation	x	x		
Accident Alert			x	
Road Hazards			x	
Traffic Congestion	x	x		
Police Stops/Information				
Live Traffic Monitoring	x	x	x	
Traffic Camera Monitoring				
User Input to Traffic Conditions			x	
User Preferences	x	x	x	x
Parking Locations				
Parking Prices				x
Parking Reservations				x
Parking Availability				x

Appendix D (United States Survey)

This survey is anonymous, and is completed at your will. The Smart City Team appreciates the time you put into this survey.

1. What is your primary mode of transportation? - Public Transportation
- Personal Car - Walking - Other (Please Specify):____________________________

2. Do you commute daily? -Yes -No

3. Do you generally follow the same route when commuting? -Yes -No

4. On average, how much time do you spend commuting daily? - 0-30 minutes
- 30- 60 minutes - 1 – 1.5 hours - 1.5 - 2 hours - 2 – 2.5 hours
- 2.5+ hours

5. Do you have a mobile device that can download apps? -Yes -No

If you answered "no" to question 5, we appreciate you taking the survey. *The survey ends here for those who answered no*

6. Do you use an app that can show you nearby traffic congestion? -Yes -No

7. Do you use an app that can show you nearby accidents or road hazards? -Yes -No

8. Do you use an app that can show you nearby parking availability? -Yes -No

9. Do you use an app that can show you nearby parking prices? -Yes -No

If you answered "yes" to at least one of questions 6-9, please answer questions 10-12. Otherwise, please continue to question 13.

10. How would you rate the importance of the following aspects of traffic and parking app(s) on a 5-point scale? (1 being low, and 5 being high)

- Affordability (do you pay little to no money for the app's services?):

1 2 3 4 5

- Reliability (does the app consistently work without glitching or crashing?)

1 2 3 4 5

- Usability (how easy is the app to use?):

1 2 3 4 5

- Effectiveness (does the app consistently do what you want it to do?):

1 2 3 4 5

11. Have you provided a rating or review for your traffic and parking app(s)? -Yes -No

12. Would you recommend your traffic and parking app(s) to someone else? -Yes -No

13. Which if any of these traffic management and parking apps have you heard of before? Check all that apply

- Waze - BestParking - Parker - Sigalert - None of the above -Other (Please Specify):

____

14. Which if any of these traffic management and parking apps do you use? Check all that apply

- Waze - BestParking - Parker - Sigalert - None of the above - Other (Please Specify):______________________

This survey then moves to direct questions about the apps they use for traffic management and parking.

The questions below are indicated on a 5-point scale (1 being low, and 5 being high)

15. How would you rate the affordability of [Insert App Here]? (do you pay little to no money for the app's services?):

1 2 3 4 5

_____________________________________ _________________

____

16. How would you rate the reliability of [Insert App Here]? (does the app consistently work without glitching or crashing?)

1 2 3 4 5

17. How would you rate the usability of [Insert App Here]? (how easy is the app to use?):

1 2 3 4 5

18. How would you rate the effectiveness of [Insert App Here]? (does the app consistently do what you want it to do?):

1 2 3 4 5

19. Please list what functions are most helpful from [Insert App Here]: _________________________

_________________________ _________________________ _________________________

____

20. Please list what functions are least helpful (Or need major improvements) from [Insert App Here]:

____

_________________________ _________________________ _________________________

____

If the surveyed person selected more than one application, these questions would repeat with each one separately.

Appendix E (Chinese Survey)

This survey is anonymous, and is completed at your will. The Smart City Team appreciates the time you put into this survey.

本次调查是匿名的，并且您可以根据您的意愿选择是否完成。我们智慧城市团队衷心感谢您的回答！

1. What is your primary mode of transportation?

    - Public Transportation
    - Personal Car
    - Motorized Scooter
    - Walking
    - Other (Please Specify): ______________________

1、您平时主要的交通方式是什么？

    -公共汽车

    -私家车

    -电瓶车

    -走路

    -其他（请详细说明）：______________________

2. Do you commute daily?

    -Yes   -No

2、您每天都要坐车吗？

    -是的   - 不是

3. Do you generally follow the same route when commuting?

    -Yes   -No

3、在坐车的时候，您通常会选择同一条路线吗？

    -是的   -不是

4. On average, how much time do you spend commuting daily?

    - 0-30 minutes
    - 30- 60 minutes
    - 1 – 1.5 hours

- 1.5 - 2 hours
- 2 – 2.5 hours
- 2.5+ hours

4、平均每天您花在路上的时间是多少？

-0-30 分钟

-30-60 分钟

-1-1.5 个小时

-1.5-2 个小时

-2-2.5 个小时

-大于 2.5 个小时

5. On average, how much distance do you spend commuting daily?

- 0-10 kilometers
- 10-20 kilometers
- 20-30 kilometers
- 30-40 kilometers
- 40-50 kilometers
- 50+ kilometers

5、平均每天您出行的路途有多长？

- 0-10 公里
- 10-20 公里
- 20-30 公里
- 30-40 公里
- 40-50 公里
- 大于 50 公里

6. Do you have a mobile device that can download apps?

-Yes -No

6、请问您有可以下载软件的移动设备吗？

-有 - 没有

If you answered "no" to question 6, we appreciate you taking the survey

如果您在第 6 个问题上回答了"没有"，我们衷心感谢您的回答。

7. Do you have a mobile app that can show you nearby traffic congestion?

-Yes -No

7、请问您有可以向您显示附近拥堵交通的手机软件吗？

- 有　　-没有

If you answered "yes" to question 7, continue to question 7.

如果您在第 7 个问题上回答了"有"，请继续回答第 8 问。

7a. If not, do you know of an app that can show nearby you traffic congestion?

-Yes　-No

7a、如果您回答了没有，□□您是否知道一款能向您显示附近拥堵交通的软件？ -

-知道　　-不知道

7b. Would you use such an app to avoid traffic?

-Yes　-No

7b、您会用这款软件来避免□堵□？

-会　-不会

8. Do you have a mobile app that can show you nearby accidents or road hazards?

-Yes　-No

8、□□您有一款能向您□示附近交通事故或者道路故障的手机□件□？

- 有　　　- 没有

If you answered "yes" to question 8, continue to question 9.

如果您在第 8 问回答了"有"，请继续回答第 9 问。

8a. If not, do you know about an app that can show you nearby accidents or road hazards?

-Yes　-No

8a、如果没有，您知道有哪款软件能向您显示附近交通事故或者道路故障吗？ -

知道 -不知道

8b. Would you use such an app to avoid traffic?

-Yes　-No

8b、您会用这款软件来避免交通□堵□？

-会　　-不会

9. Do you have a mobile app that can show you nearby parking availability?

-Yes　-No

9、请问您是否有一款能向您显示附近有能用的停车位的手机软件？

-有　　-没有

If you answered "yes" to question9, continue to question 10.

如果您在第 9 问回答"有"，请继续回答第 10 问。

9a. If not, do you know about an app that can show you nearby parking availability?

-Yes -No

9a、如果没有，您知道有哪款软件可以向您显示附近有能用的停车位吗？

-知道 -不知道

9b. Would you use such an app to save time and go directly to a parking spot?

-Yes -No

9b、您会使用这类软件来节约时间，并且根据它的提示直接去能用的停车点吗？ -

-会 -不会

10. Do you have a mobile app that can show you nearby parking prices?

-Yes -No

10、请问您有一款能向您显示附近停车位价格的手机软件吗？

-有 -没有

If you answered "yes" to question 9, continue to question 10.

如果您在第 9 问回答了"有"，请继续回答第 10 问。

10a. If not, do you know about an app that can show you nearby parking prices?

-Yes -No

10a、如果没有，您知道有哪款□件能向您显示附近停车位价格吗？

-知道 -不知道

10b. Would you use such an app to save time and go directly to a parking spot?

-Yes -No

10b、您会使用□□□件来□□□□，并且根据它的提示直接去停□点□？

-会 -不会

Appendix F (United States and Chinese Survey Responses)

F.1 Traffic Information Graphs

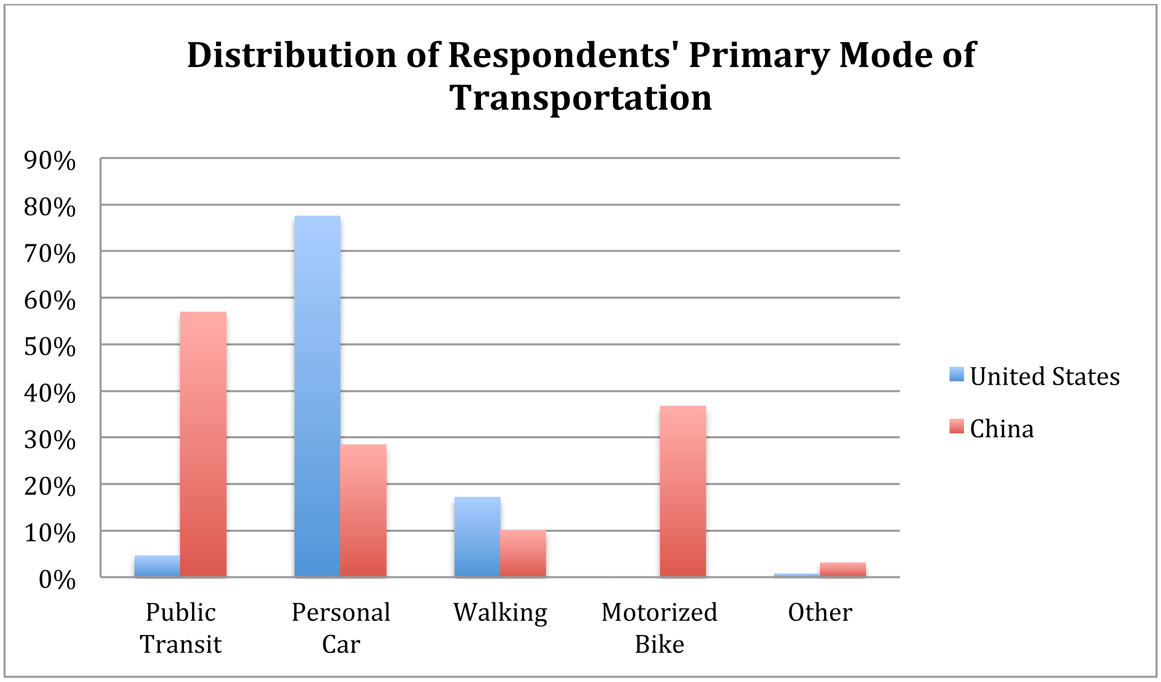

Figure F1: United States and Chinese primary mode of transportation

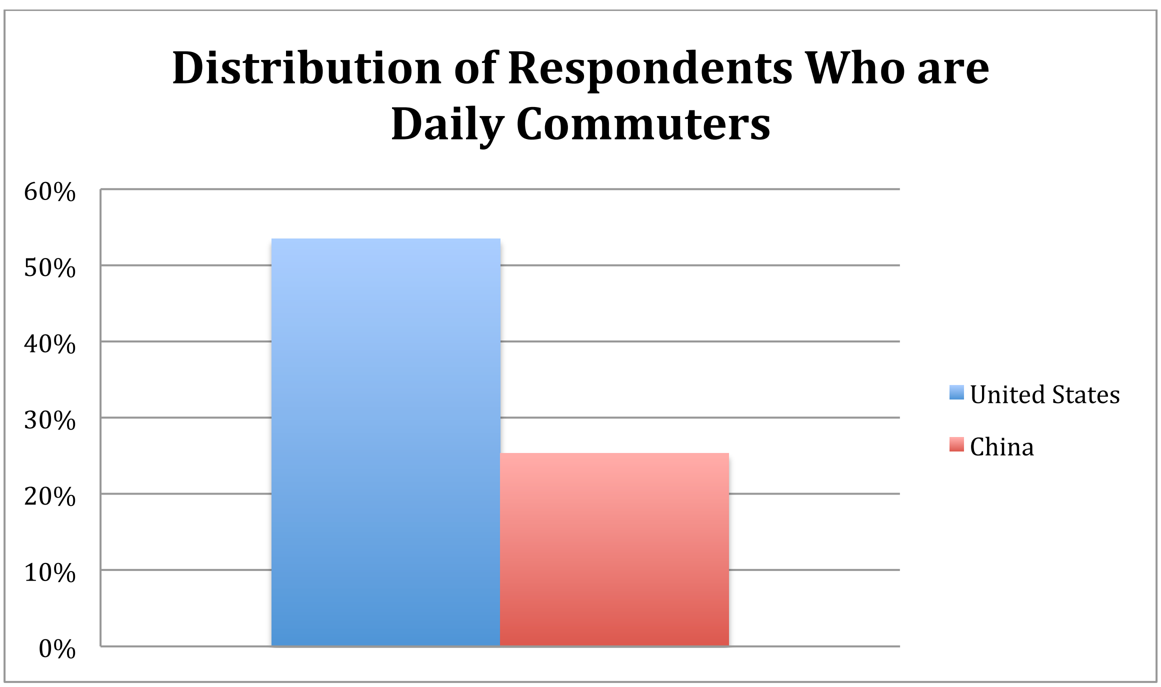

Figure F2: United States and Chinese percentage of daily commuters

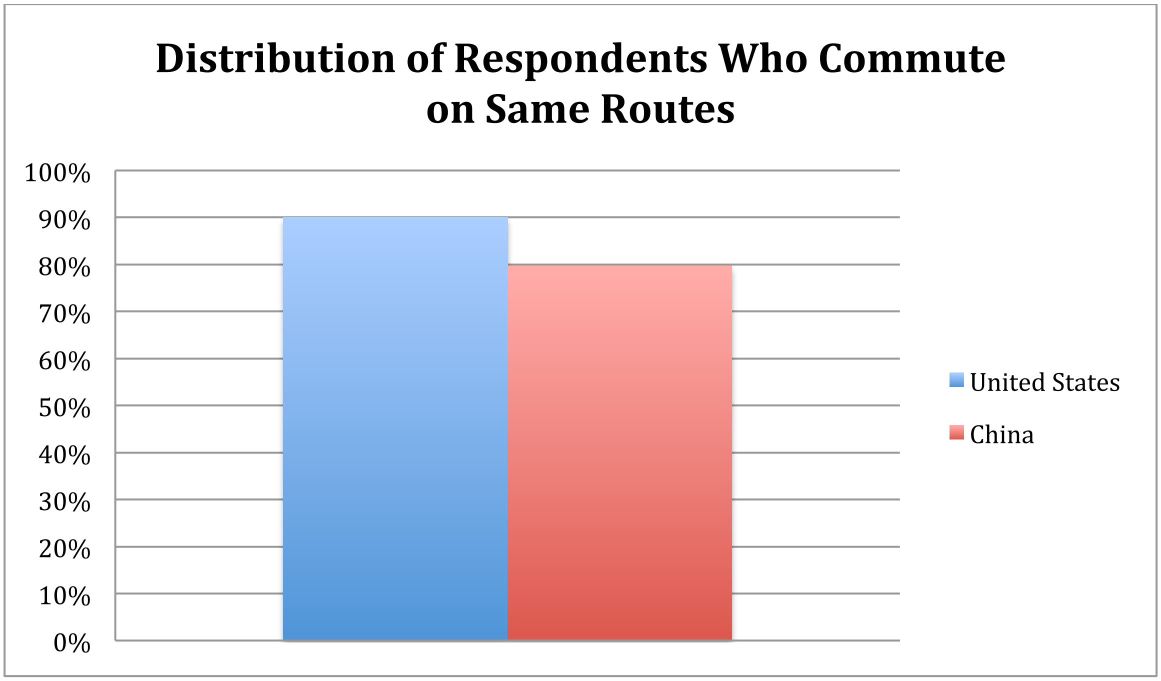

Figure F3: Percentage of daily commuters who use the same route

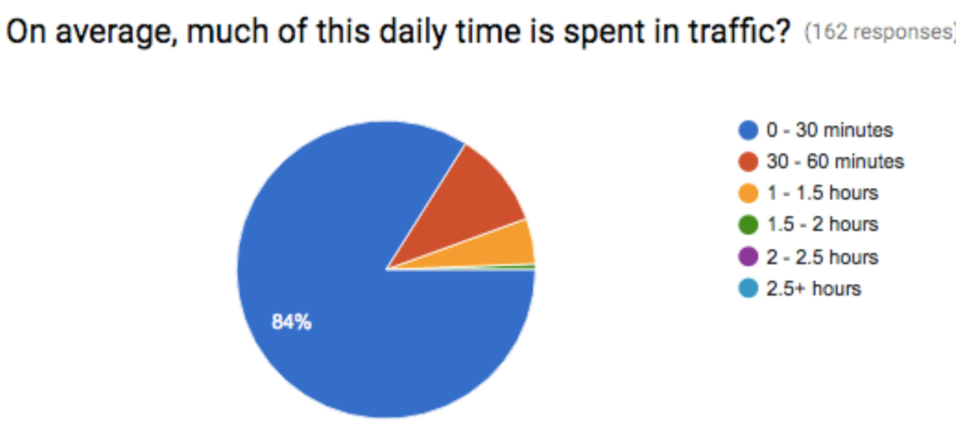

Figure F4: United States time spent in traffic

F.2 Traffic Management Application Function Information

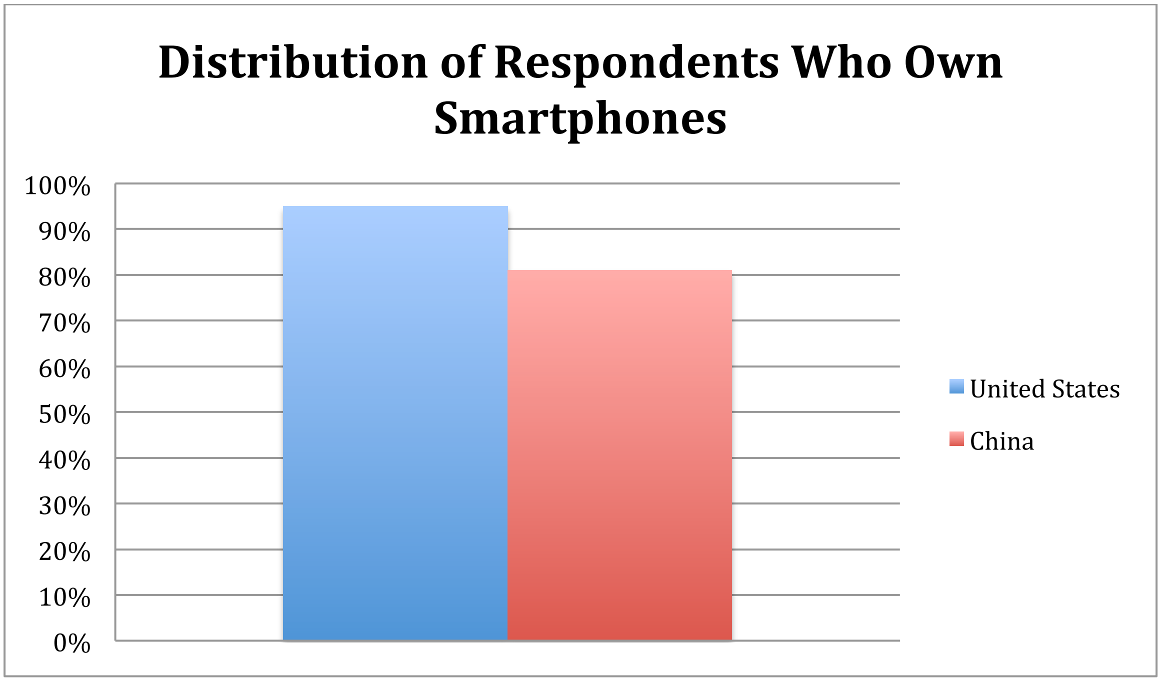

Figure F5: Smartphone usage in the United States and China

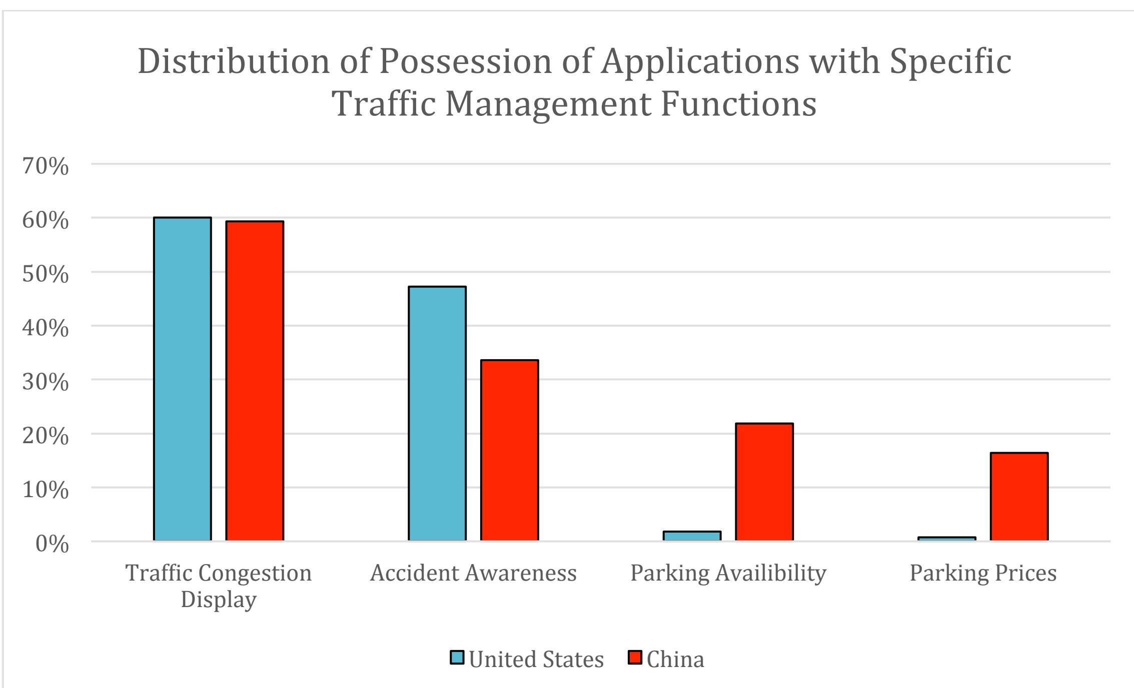

Figure F6: Possession of applications with specific traffic management functions in the United States and China

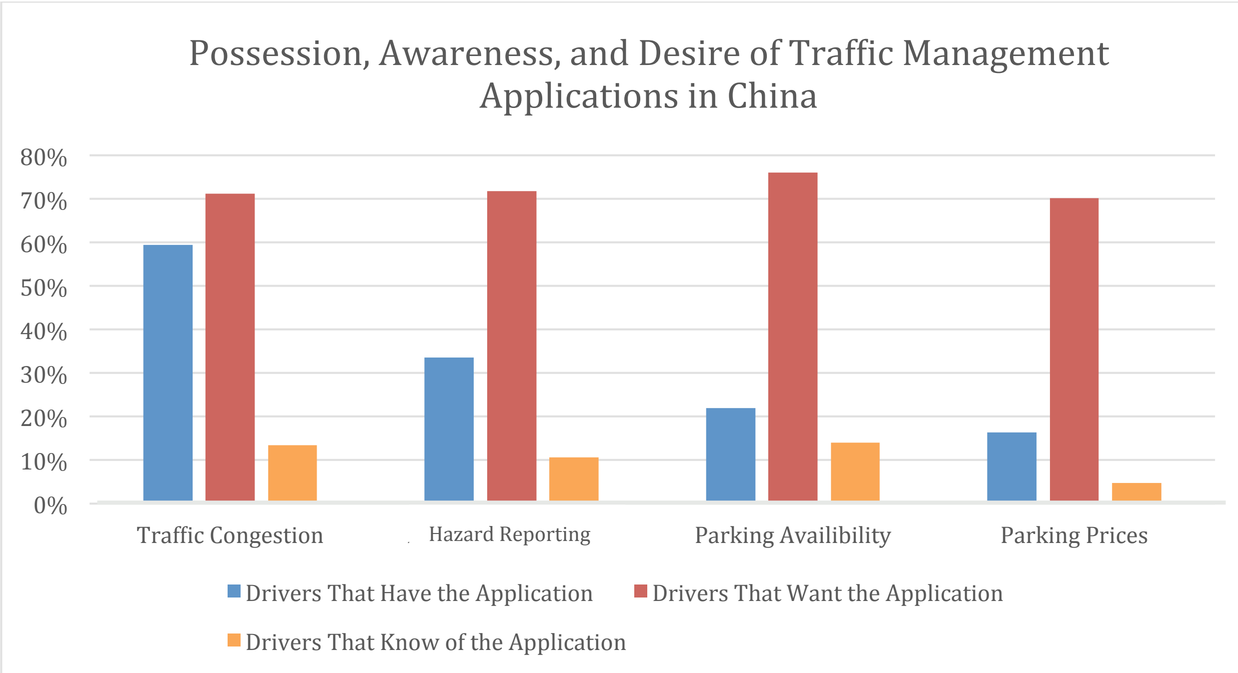

Figure F7: Possession, awareness, and desire of traffic management applications in China

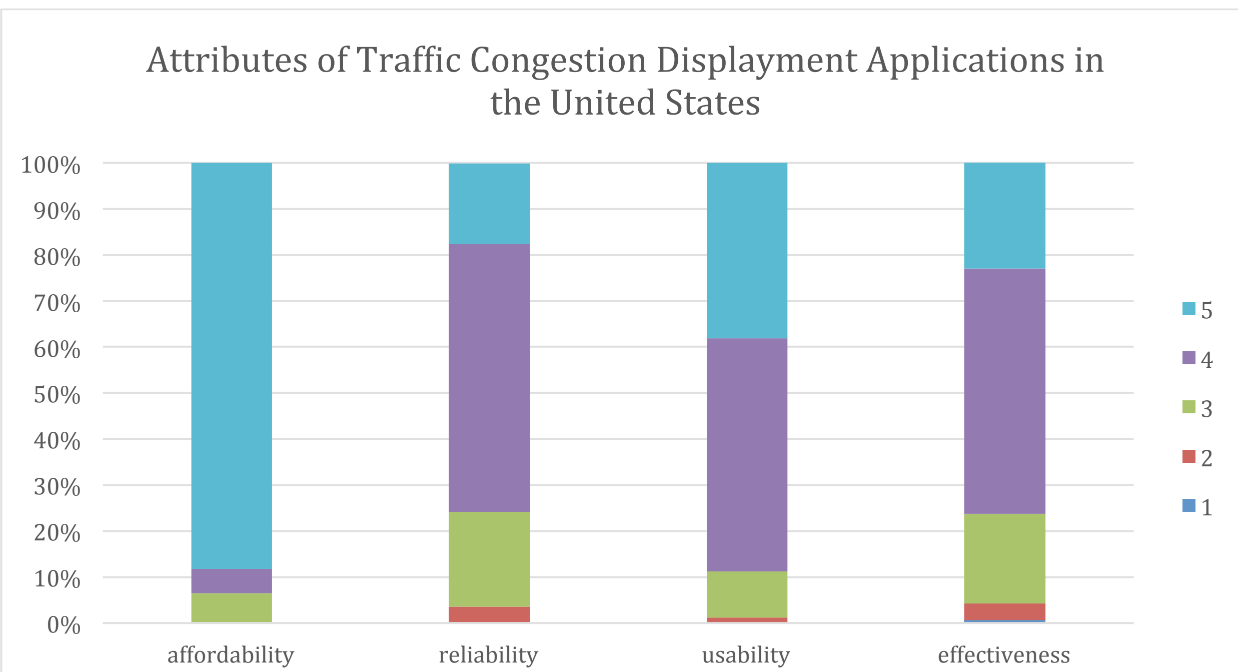

Figure F8: Attributes of traffic congestion display applications in the United States

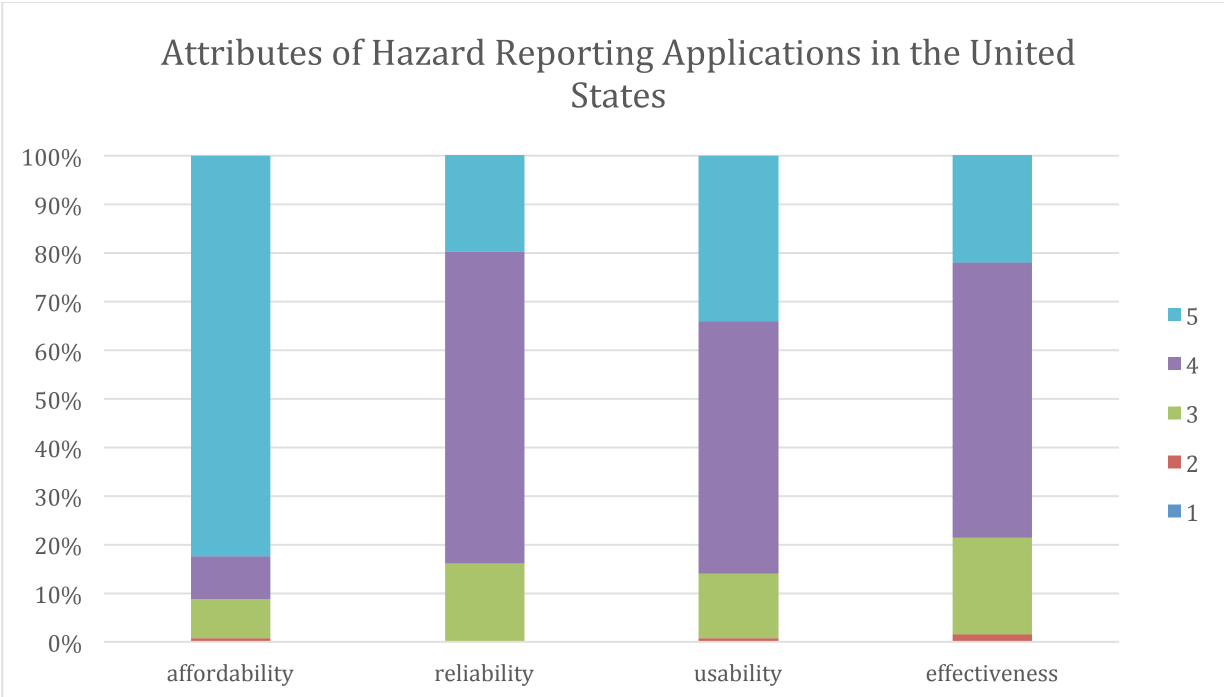

Figure F9: Attributes of hazard reporting applications in the United States

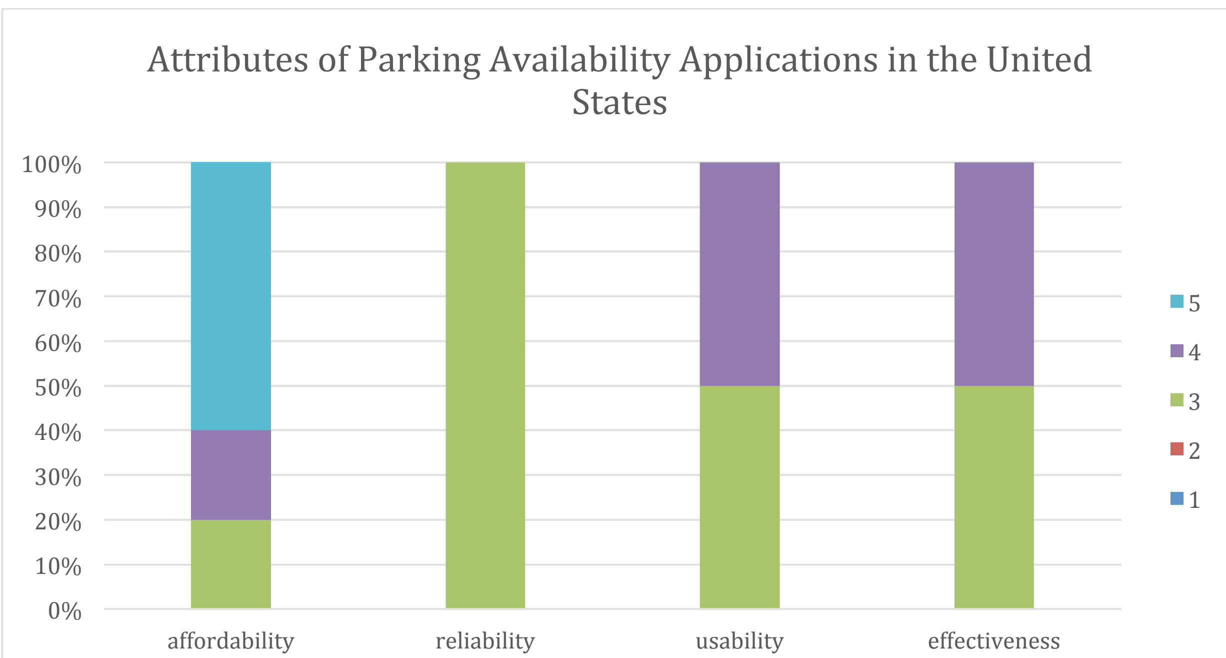

Figure F10: Attributes of parking availability applications in the United States

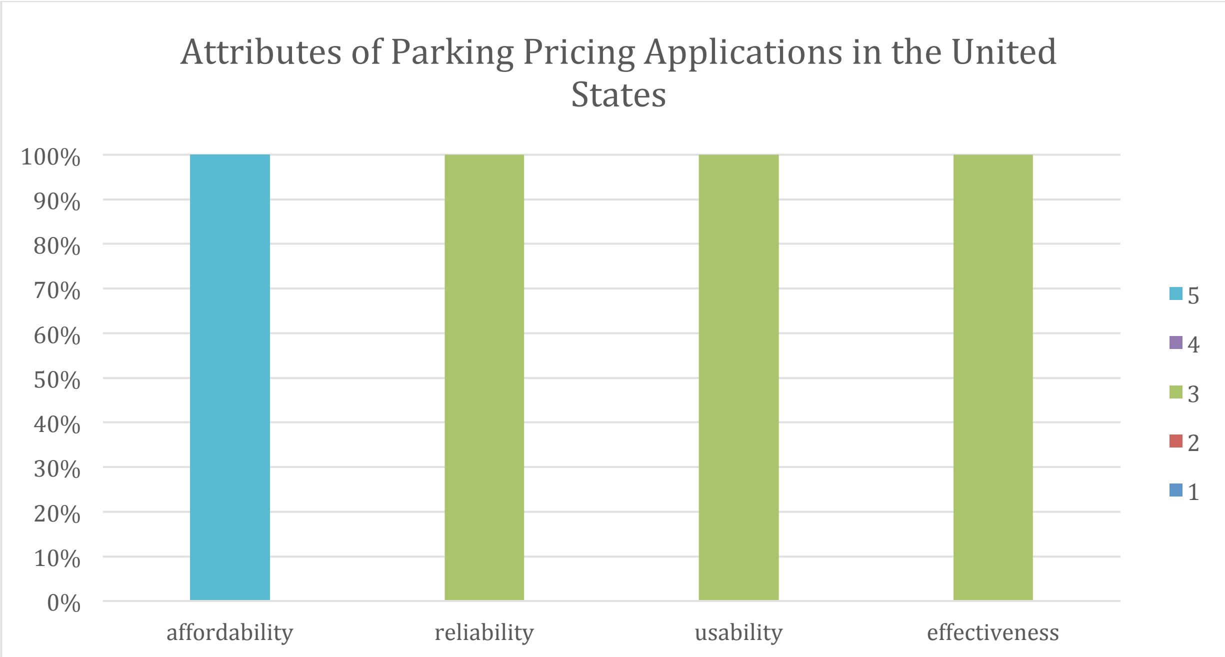

Figure F11: Attributes of parking pricing applications in the United States

F.3 Specific United States Traffic Management Application Information

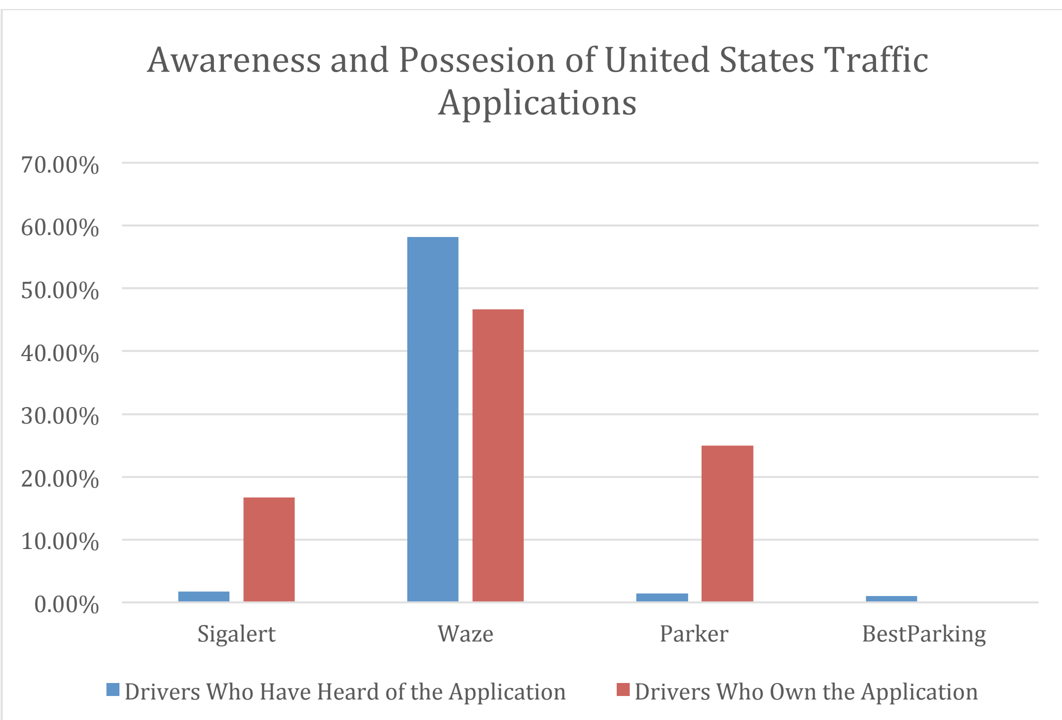

Figure F12: Awareness and possession of United States traffic applications

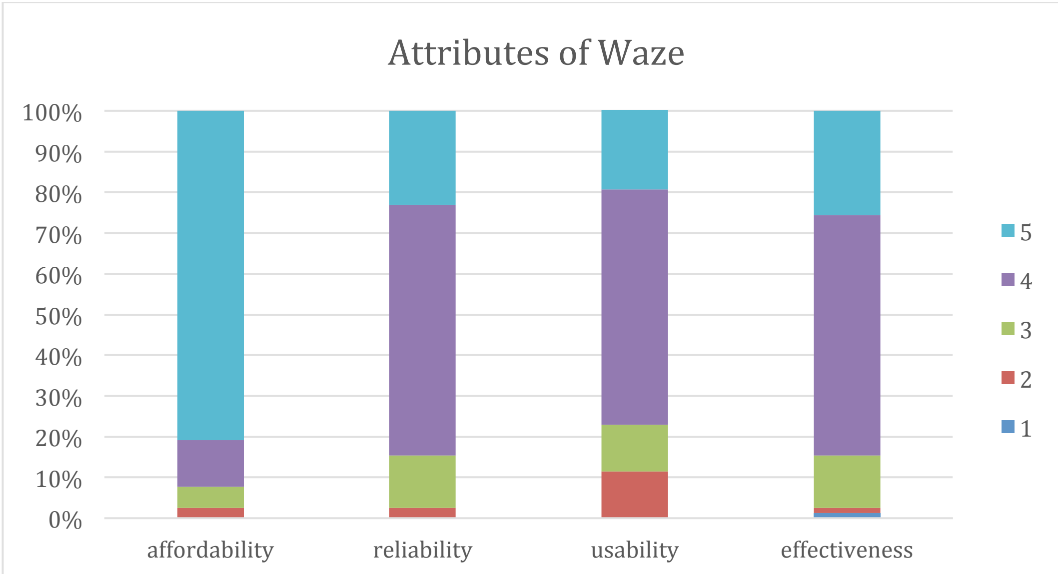

Figure F13: Attributes of Waze by percentage of users

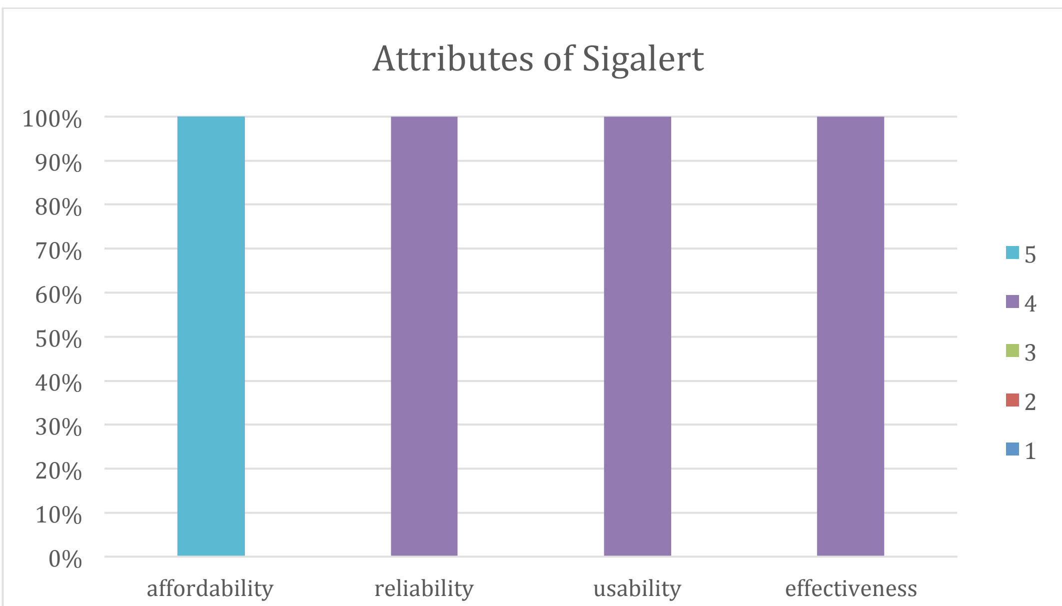

Figure F14: Attributes of Sigalert by percentage of users

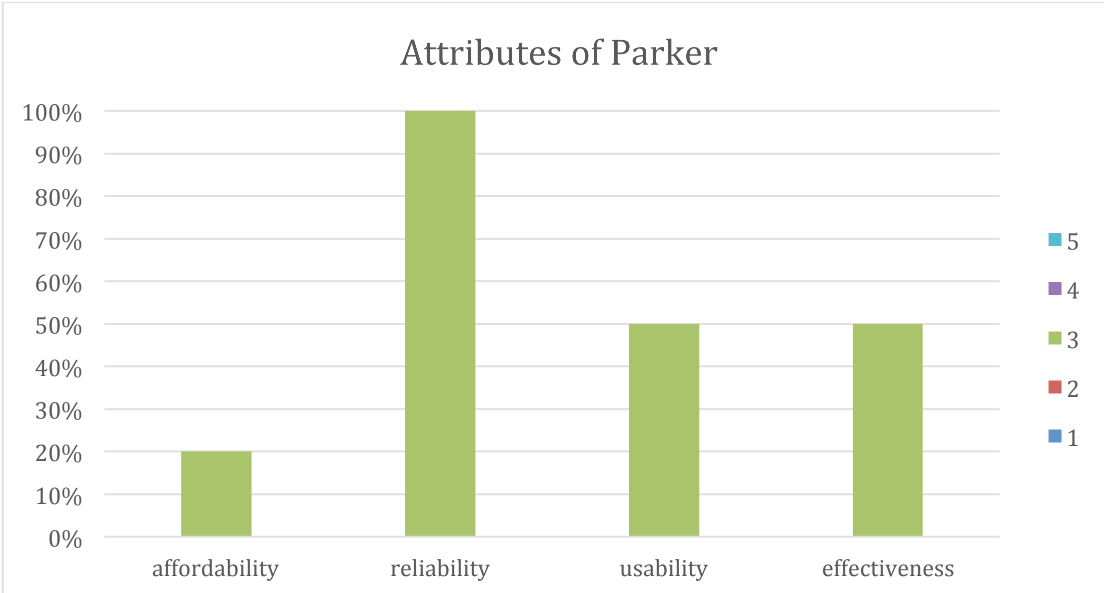

Figure F15: Attributes of Parker by percentage of users