DEVELOPING FUTURE SMART PARKING SOLUTIONS FOR HANGZHOU'S IOT TOWN

MICHAEL ALTAVILLA, JOSUE CONTRERAS, EVAN LEBEAU, SHUXING LI

REPORT SUBMITTED TO:

PROFESSOR QI LIU
SMART CITY RESEARCH CENTER OF ZHEJIANG PROVINCE

PROFESSOR WEN-HUA DU
PROFESSOR KINICKI
WORCESTER POLYTECHNIC INSTITUTE

Developing Future Smart Parking Solutions for Hangzhou's IoT Town

An Interactive Qualifying Project Report
Submitted to the Faculty
of
WORCESTER POLYTECHNIC INSTITUTE

WPI

in partial fulfilment of the requirements for the
Degree of Bachelor of Science
by:

Michael D. Altavilla
Josue D. Contreras
Evan R. LeBeau
Shuxing Li

Sponsored by:
Professor Qi Liu
Smart City Research Center of Zhejiang Province

杭州電子科技大学
HANGZHOU DIANZI UNIVERSITY

Date: December 9

Report Submitted to:
Professor Robert E. Kinicki
Professor Wen-Hua Du

This report represents work of WPI undergraduate students submitted to the faculty as evidence of a degree requirement. WPI routinely publishes these reports on its web site without editorial or peer review. For more information about the projects program at WPI, see http://www.wpi.edu/Academics/Projects

Abstract

With help from the Smart Cities Research Center of Zhejiang Province, this project aimed to assess and improve current smart parking solutions in Hangzhou, China. The team consulted industry experts and research students to gauge the direction of smart technology applicable to future parking solutions. The team analyzed results from interviews, customer surveys, and observations to infer needs for improved user experience. Research performed on future technologies allowed the team to offer a system framework recommendation with modern smart parking features for a characteristic town in Hangzhou. The project team discovered that a future smart parking system could integrate 5G, High-Frequency RFID, and non-contact payment methods to address the shortcomings of current smart parking systems.

Acknowledgments

The team acknowledges that the help of a few select individuals helped them succeed and make the most of their time spent in Hangzhou. The following individuals and groups deserve recognition for their continual support in helping the team accomplish the project goals.

Thank you for the following contributions:

- Professor Kinicki, for providing prompt feedback and guidance in writing the final IQP report, and being a supportive project advisor.
- Professor Du, for her enthusiasm for the project and support while adapting to Chinese culture, and providing detailed feedback as a co-advisor.
- The HDU "Buddies", for their friendship and support of the project team. Each HDU student played a vital role in the team's data collection while interacting with the citizens of Hangzhou.
- The Hangzhou Dianzi University and their faculty for the hospitality and support of all six WPI project groups.
- Professor Qi Liu, the project sponsor for her continual effort in facilitating research opportunities for the project team, and being a valuable asset while learning about the developments of modern smart parking. Her organization and scheduling of the project, which ultimately led to the project's success was a product of her active involvement and guidance while working alongside the project team.

Executive Summary

Hangzhou is a large metropolitan city that serves as a hub for manufacturing and textile industries in China. During the industrialization of Hangzhou, the associated factories attracted inland workers seeking employment. As a result of this rapid industrialization, Hangzhou, China created industry characteristic towns to centralize companies with common fields of development. Characteristic towns typically take form as a grouping of companies sharing property in order to foster innovation and industry growth in similar fields of expertise. The city's population of 9.46 million people has increased by 0.28 million from 2017 - 2018 (Survey Department of Hangzhou, 2018). The developing population and the new social normality of owning a vehicle have led to a substantial increase in registered vehicles each year. A total of 342 million people now have drivers' licenses in China, which is an 11.84% increase in less than a year (Gao, 2018). Hangzhou's size has led to a limited number of parking spaces and the ratio of available parking spaces to vehicles decreases further each year as the number of vehicle registration increases.

High population density environments such as Hangzhou typically fall victim to less efficient city management. Over the past few decades, there have been continual efforts in the form of smart city developments to improve city efficiency. While smart cities have grown all over the globe, "China is home to a staggering 500 smart city pilots, which is half of the worlds developing smart cities" (Lin, 2018, p.1). In Hangzhou, China, the motivation and need for a smart city is a rapid increase in population and urbanization. Cars were not always as prevalent in Hangzhou because of a substantial social class divide. However, in recent years, the social class division has lessened due to an increasing middle class. The city management plan integrated simple smart parking solutions once vehicles became a social normality in Hangzhou. With the rapid growth of registered vehicles, the need for more efficient parking solutions has become far more urgent. Researchers have begun developing smart parking solutions to increase parking efficiency and alleviate unnecessary city congestion. While technologies are still in development, Hangzhou's total traffic declined by 12.5% in 2018 through the implementation of smart parking, even when the population grew by 3% (Hao, 2018).

The surge of vehicle registration has exposed the weaknesses of the inefficient current smart parking solutions in Hangzhou. Many of the current smart parking complexes have simple control systems that enable a car to enter and exit a parking area. This solution is adequate for access control; however, the system offers no additional information such as parking space availability and parking space locations. Smarter systems that incorporate additional real-time data to provide a better user experience would allow parking complexes across the city to individually operate more efficiently; ultimately decreasing traffic congestion and improve parking convenience. Internet of Things companies and smart city researchers in Hangzhou are actively researching various technologies that improve parking management across the city.

This project focuses on studying improved communication and sensing technologies to suggest a future smart parking solution for an Internet of Things town (IoT) in Hangzhou, China.

With help from the Smart City Research Center of Zhejiang Province, the project team explored the needs of smart parking consumers and providers in order to develop recommendations that address challenges with the current parking systems. The project team attempted to consult a relevant demographic of consumers from the surrounding community to understand the current smart parking systems and their challenges in Hangzhou.

The team gathered data through three separate data collection methods. The conducted naturalistic observations, customer surveys, and expert interviews allowed the team to infer consumer and provider needs for future smart parking systems in Hangzhou. In order to ascertain results from each data collection method, the team used a combination of coding techniques and survey question clustering to reveal recurring themes and highlight the shortcomings of current parking practices. The team researched potential technologies to analyze their feasibility within future smart parking solutions. Our SWOT analyses assisted in identifying and qualifying key qualities of both current and future technological solutions. The findings from the analysis directed the team towards the characteristics of their proposed system framework presented to the project sponsor.

First, to gain a better understanding of typical parking solutions available in Hangzhou, the team observed six different parking locations with similar characteristics and customers of the IoT town (see Figure 1). The data collected during these observations provided insight into the current design and effectiveness of the smart parking complexes in Hangzhou. The compiled data recorded during observations shed light on the fact that the current parking complexes all utilized non-contact payment methods, optical character recognition (OCR) cameras, and employed a large amount of personnel. At the four observed public parking complexes, the team distributed seventeen customer surveys to gain an understanding of overall customer experience and satisfaction. Two parking complexes were more traditional, with technology only applied at the front gate. The other parking complexes had far more complex applied smart technologies, such as LED lights which navigated vehicles to available parking spaces marked by OCR cameras above each parking space. By clustering similar responses, the team uncovered three results.

Figure 1: Map of observation locations, Hangzhou China

The team noted that regardless of the smart system's technique for marking occupied parking spots, the customers found it difficult to find an available parking space. This finding suggests that the current practice of using OCR was ineffective in identifying open parking spots within Hangzhou's parking complexes. Additionally, the inconveniences noted by customers led the team to infer that the overall use of technology was insufficient, and at times faulty in operation. Lastly, the survey responses qualified the discovered trends relevant to the project scope in that generally consumers parking near their place of employment.

The final obtained qualitative data was the opinions from expert interviews that the team conducted with members of PShare Company, Alibaba, and research graduate students from the Smart City Research Center of Zhejiang Province. The team analyzed each interview by coding the recorded transcripts from each interview. Interview results suggest that integrating multiple technologies could fix the current smart parking system challenges. The subjects advised that 5G and RFID technologies should be viable for future developments. One important commonality between the responses of all three survey groups was that current parking space availability was most important to record in a system and display accurately in order to satisfy consumers and provider needs. Acknowledgments made by interview subjects recognizing current practices, such as OCR cameras, possibly becoming obsolete in the near future further supported these results. Interview subjects from Alibaba expected emerging technological solutions such as non-contact payment methods and improved vehicle sensing technologies to support future smart parking solutions.

With some similar results from each of the three data collection methods, the team drew parallels between recurring trends seen in the result of each method. The observed ineffectiveness of current vacancy identification methods along with survey and interview responses led the team to infer a major need of consumers and providers is improved availability and vacancy identification. The team discerned that the use of more effective technology to identify vehicles could minimize the amount of management personnel and drive down the consumer costs. With the current social norm of using non-contact payment methods, the team favored the integration of mobile devices to mitigate time spent paying for parking complexes and ultimately increase convenience.

With the consumer and provider needs in mind, the team determined potential technological solutions to research. After some general background research, the team performed SWOT analysis on two separate solution groups. By focusing on the potential communication methods and sensing technologies, the team analyzed the strengths and weaknesses of all considered solutions. The findings of the SWOT analyses led the team to believe that RFID used alongside 5G communication technologies had the greatest potential of streamlining the customer identification process and improving the user experience.

The final recommendations for the Smart City Research Center of Zhejiang Province consisted of a future smart parking system that leverages the parking locks that PShare Co. is currently developing (as seen in Figure 2). PShare's current parking locks use Bluetooth technology to control access to available parking spaces. These parking locks in their current state are adequate for a temporary solution, however, a future solution may incorporate 5G and

RFID technologies to increase parking efficiency and the overall customer experience within the complex. By implementing 5G technology into PShare's future models, a future parking solution can wirelessly connect the parking locks and other devices. Improved communication technologies mitigate the need for extraneous personnel and create additional opportunities for further integration of mobile devices. The system design could utilize Alipay for a convenient payment method and navigation interface through Alipay's mini-app platform on the consumers' phones. The increased communication between all aspects of the recommended system aims to increase customer satisfaction through more effective use of applied technology while mitigating the time a customer spends parking their vehicle.

Figure 2: PShare-01ZU parking lock with Zigbee capability (PShare, n.d.)

The team designed the final recommendations to influence the identification process of a future smart parking system's characteristics for the IoT town. The suggested system framework, while not fully developed due to the time constraints of this project, outlines valuable information on the application potential of future smart technologies. The project team suggests that the Smart City Research Center of Zhejiang Province leverage our findings to guide the system design of future smart parking solutions in Hangzhou, China.

Authorship

Sections	Primary Author(s)	Primary Editor(s)
Final Document Formatting	Josue	All Authors
Title page	All Authors	All Authors
Abstract	Evan/Michael	Evan/Michael
Acknowledgments	Michael	Michael/Josue
Executive Summary	Evan/Michael	Evan/Michael
Authorship	Josue	All Authors
Tables of Contents and Abbreviations & Notations	Josue	Josue
Chapter 1: Introduction	All Authors	Evan/Michael
Chapter 2: Background		
2.1 The Smart City Concept	Josue	All Authors
2.1.1 Defining a Smart City	Josue	All Authors
2.1.2 Breaking Down the Smart City Model	Josue	All Authors
2.1.3 Developed Smart Cities	Josue	All Authors
Barcelona	Josue	All Authors
London	Josue	All Authors
2.1.4 Developing Smart Cities in China	Josue	All Authors
Shanghai	Josue	All Authors
Hangzhou	Josue	All Authors
2.2 Hangzhou City Background	Shuxing	All Authors
2.2.1 Current Vehicle Influx	Shuxing	All Authors
2.2.2 China's Approach to Parking Management	Shuxing	All Authors
2.2.3 The Concept of a Characteristic Town	Shuxing	Evan/Michael
2.2.4 The Wide Usage of New Payment Methods	Shuxing	Evan/Michael
2.3 Current Smart Parking Solutions	Evan	All Authors
2.3.1 Smart Parking Systems	Evan	All Authors
2.3.2 Parking Guidance and Information Systems (PGIS)	Evan	All Authors
2.3.3 Transit Based Information Systems	Evan	All Authors
2.3.4 Smart Payment Systems	Evan	All Authors
2.3.5 E-Parking	Evan	All Authors
2.3.6 Automated Parking	Evan	All Authors
2.3.7 Mobile Applications Potential	Evan	All Authors
2.3.8 The Development of Smart Parking Systems in China	Michael	All Authors
2.3.9 Opposing factor to Smart Parking Development	Michael	All Authors
2.4 Supporting Smart Parking Technologies	Michael	Evan/Michael
2.4.1 Optical Character Recognition Cameras	Michael	Evan/Michael
2.4.2 Infrared Sensor Systems	Michael	Evan/Michael
2.4.3 Bluetooth Communication Integration	Michael	Evan/Michael
2.4.4 Electromagnetic Field Sensors	Michael	Evan/Michael
2.5 RFID Hardware Solutions	Michael	All Authors
2.5.1 RFID High Level Overview	Michael	All Authors
2.5.2 Passive, Active, and Semi-Active RFID	Michael	All Authors
2.5.3 Applications of Specific RFID Technologies	Michael	All Authors
2.5.4 RFID Hardware in Smart Parking Systems	Michael	All Authors
2.6 RFID Infrastructure	Evan	All Authors

2.6.1 RFID Host Computer	Evan	All Authors
2.6.2 Middleware	Evan	All Authors
2.7 Utilizing RFID Technology	Josue	All Authors
2.8 Local Regulations	Shuxing	All Authors
2.8.1 Local Laws Regarding Parking	Shuxing	All Authors
2.8.2 Local Laws Regarding RFID Technology and Data	Shuxing	All Authors
2.9 Characteristics of a Solution	Evan/Josue	Evan/Michael
2.9.1 Payment Methods	Josue	Evan/Michael
2.9.2 Localization Technique	Josue	Evan/Michael
2.9.3 Reservation Technique	Evan	Evan/Michael
2.9.4 Device and Equipment Location	Evan	Evan/Michael
2.9.5 Vacancy Identification	Josue	Evan/Michael
2.9.6 Navigation Interface and Technology	Evan	Evan/Michael
2.10 Summary	Michael	All Authors
Chapter 3: Methodology		
3.1 Objective One: Study Hangzhou's Current Smart Parking Systems	Michael	Evan/Michael
3.1.1 Observe System Infrastructure and Customer Interaction	Michael	Evan/Michael
3.1.2 Select Stakeholders for Consultation	Michael	Evan/Michael
Industry Experts	Michael	Evan/Michael
Smart Parking Customers	Michael	Evan/Michael
Graduate Research Students at Hangzhou Dianzi University	Michael	Evan/Michael
3.1.3 Consult Primary Stakeholders	Michael	Evan/Michael
Industry Interviews	Michael	Evan/Michael
Public Surveying	Michael	Evan/Michael
3.1.4 Infer Consumer and Provider Needs	Michael	Evan/Michael
3.2 Objective Two: Evaluate Potential Smart Parking Solutions	Evan	Evan/Michael
3.2.1 Research Potential System Elements	Evan	Evan/Michael
3.2.2 Compare & Analyze Feasibility of Researched Solutions	Evan	Evan/Michael
3.3 Objective Three: Present Recommendations and Report Findings to Sponsor	Josue	Evan/Michael
3.3.1 Determine the Recommended Solution	Josue	Evan/Michael
3.4 Summary	Evan	Evan/Michael
Chapter 4: Results and Analysis of Collected Data		
4.1 Results and Analysis of Natural Observation Period	Josue	Evan/Michael
4.1.1 Summary of Jinhui Parking Complex Observation	Evan	Evan/Michael
4.1.2 Summary of Peace Square Parking Complex Observation	Michael	Evan/Michael
4.1.3 Summary of Qianjiang New Town Time Square Parking Complex Observation	Michael	Evan/Michael
4.1.4 Summary of Qiantang Hangkong Parking Complex Observation	Josue	Evan/Michael
4.1.5 Summary of Zunbao Building Parking Complex Observation	Shuxing	Evan/Michael
4.1.6 Summary of Huawei Parking Complex Observation	Evan	Evan/Michael
4.1.7 Summary of Observation Period Findings	Evan	Evan/Michael
4.2 Results and Analysis of Surveys	Michael	Evan/Michael
4.2.1 Survey Demographic Findings	Josue	Evan/Michael
4.2.2 Parking Availability and Applied Technology Findings	Michael	Evan/Michael
4.2.3 Vacancy Identification Findings	Michael	Evan/Michael
4.2.4 Summary of Findings from Parking Complex Public Surveys	Michael	Evan/Michael
4.3 Results and Analysis of Interviews	Michael	Evan/Michael
Hangzhou PShare Company	Michael	Evan/Michael

Table of Contents

List of Figures

List of Tables

Abbreviations and Notations

AI:	Artificial Intelligence
API:	Application Program Interface
AV:	Automated Vehicle
CCTV:	Closed Circuit Television
CNY:	Chinese Yuan
4G:	Fourth Generation of Broadband Cellular Network Technology
5G:	Fifth Generation of Cellular Mobile Communication
HDU:	Hangzhou Dianzi University
HF:	High Frequency
ICT:	Information and Communication Technology
IoT:	Internet of Things
LED:	Light Emitting Diode
LORA:	Long Range (digital wireless data communication technology)
NB-IoT:	Narrow Band Internet of Things
MPS:	Ministry of Public Security of the People's Republic of China
OCR:	Optical Character Recognition
PCB:	Printed Circuit Boards
PGIS:	Parking Guidance and Information System
QR Code:	Quick Response Code
RFID:	Radio Frequency Identification
SWOT:	Strengths Weaknesses Opportunities Threats
UHF:	Ultra-High Frequency
WPI:	Worcester Polytechnic Institute

Chapter 1: Introduction

The modern city evolved as a result of rapid industrialization and increased population density around production hubs. In the past two decades, the need for more efficient cities has come as a product of their development, in the form of increased manufacturing and the creation of a corporate culture. The growing industries within cities attract more citizens annually in search of employment. With a population of 9.4 million people, the city of Hangzhou quickly developed as a technological hub for many industry leaders in China. As a result of this rapid industrialization, Hangzhou, China created industry characteristic towns to localize companies with common fields of development. Characteristic towns typically take form as a grouping of companies sharing property in order to foster innovation and industry growth in similar fields of expertise.

Cities overcrowded for residents and visitors are often the result of numerous corporations constructed each year. The need for more efficient city logistics has influenced the use of technology to assist with modern city challenges. Fueled by the technological revolution, a city approach known as a smart city has emerged as a solution. Some of the largest and most densely populated cities in the world have adopted smart city concepts to collect real-time data and connect applied technologies to create a more efficient city life.

Hangzhou is a large metropolitan city that serves as a hub for manufacturing and textile industries in China. During the industrialization of Hangzhou, the associated factories attracted inland workers seeking employment. The city's population of 9.46 million people has increased by 0.28 million from 2017 - 2018 (Survey Department of Hangzhou, 2018). The developing population and the new social normality of owning a vehicle has led to a substantial increase in registered vehicles each year. A total of 342 million people now have a driver's license in China, which is an 11.84% increase in less than a year (Gao, 2018). Hangzhou's size has led to a limited number of parking spaces and the ratio of available parking spaces to vehicles decreases further each year as the number of vehicle registration increases.

High population density environments such as Hangzhou typically fall victim to less efficient city management. Over the past few decades, there have been continual efforts in the form of smart city developments to improve city efficiency. Smart cities are the result of a technological revolution effectively coupled with the modern vision known as the Internet of

Things (IoT). Together, they signify a modern 'high-tech' response to urban problems. While smart cities have grown all over the globe, "China is home to a staggering 500 smart city pilots, which is half of the worlds developing smart cities" (Lin, 2018, p.1).

In Hangzhou, China, the motivation and need for a smart city mentality is a rapid increase in population and urbanization. Cars were not always as prevalent in Hangzhou because of a substantial social class divide. In recent years, the social class division has lessened due to the reduction in social class separation. The city management plan integrated simple smart parking solutions once vehicles became a social normality in Hangzhou. With the rapid growth of registered vehicles, the need for more efficient parking solutions has become far more urgent. Researchers have begun developing smart parking solutions to increase parking efficiency and alleviate unnecessary city congestion. While technologies are still in development, Hangzhou's total traffic declined by 12.5% in 2018 through the implementation of smart parking, even when the population grew by 3% (Hao, 2018). This trend supports the belief that continued improvements to the smart parking solution will mitigate city congestion despite an ongoing increase in population and car ownership in Hangzhou.

While the current smart parking solutions in Hangzhou have had a positive impact on city congestion, there is still potential for a far more efficient system. The rapid growth of Hangzhou's population and the subsequent increase in registered vehicles has exacerbated the inherent inefficiencies in Hangzhou's current smart parking solutions. With an estimated 30% of traffic in urban settings due to vehicles searching for parking, a solution that assists in finding available parking could mitigate a large portion of the city congestion (Vesco, 2015). Many of the current smart parking complexes have simple control systems that enable a car to enter and exit a parking area. This solution is adequate for access control; however, such systems offer no additional information such as parking space availability and parking space locations. A smarter, more comprehensive system that incorporates additional real-time data to provide better user assistance would allow parking complexes across the city to individually operate more efficiently; ultimately decreasing traffic congestion and improve parking convenience.

Most of the smart parking solutions previously implemented into Hangzhou utilized simple Radio Frequency Identification (RFID) systems as a form of vehicle identification and parking management. While these systems were adequate for site-specific vehicle management, they have become inefficient. The surge of vehicle registration has exposed the weaknesses

within these systems. Internet of Things companies in Hangzhou are actively researching various technologies that improve parking management across the city. Incorporating multiple technological subsystems could remove extraneous management personnel and improve vehicle safety. These systems would also have the ability to integrate with a user interface on mobile devices that could provide drivers with information regarding parking availability. These innovative options would direct customers to desired parking spots based on feedback data sourced from sensors throughout a parking complex.

This project focuses on studying RFID and additional information technologies to suggest a smart parking system for a characteristic town in Hangzhou, China. With the help of Professor Qi Liu and graduate research students from the Smart City Research Center of Zhejiang Province, the project team explored the needs of Hangzhou citizens and developed recommendations that addressed challenges with the current parking systems. The project team performed observations, surveys, and interviews in the surrounding area to understand the current smart parking systems and their challenges in Hangzhou. Analysis of these results yielded consumer and provider needs that guided further research on smart parking technologies that were possible for the Internet of Things (IoT) town. The consumer and provider needs guided further research on smart parking technologies that were possible for the Internet of Things (IoT) town. The final recommendation was a smart parking system designed to improve the parking efficiency of a characteristic town through the use of improved communication technologies. By proposing the application of these technologies with physical parking locks and mobile applications, the recommendations have the potential to test the deployment of future smart technologies within the IoT characteristic town. Researchers and experts can use the team's research and supporting data as a catalyst to propel smart parking research in Hangzhou.

Chapter 2: Background

This chapter outlines the universal concept of a smart city and potential technologies to cultivate an improved parking system for a characteristic town in Hangzhou. The project team describes the historical background of Hangzhou and explains the demand for smart city implementation within China. Furthermore, the team analyzes successful smart city developments around the globe and the impact applied technology has on community needs. The team assesses communication and sensing technologies and highlights their roles within developing smart parking systems. The project team supports these ideas by depicting possible technologies for a future smart parking solution and how they fulfill the project sponsor's goals.

2.1 The Smart City Concept

2.1.1 Defining a Smart City

The definition of a smart city is abstract in nature and thus open to interpretation. Popular opinion defines a smart city as a city that implements information and communication technology (ICT) and innovative ideas to facilitate the improvement of urban sub-systems (Cheng, 2015). While there is not a concrete definition for a smart city, diverse urban environments universally conceptualize smart cities as elegantly efficient. The development of smart cities has brought forth new opportunities for citizens such as increased employment opportunities, wealth creation and economic growth. The perceived definition of a smart city is largely dependent upon an individual's interaction with the technology integrated within the city around them. This results in a diverging opinion, qualified by site-specific needs of each unique region (Glasmeier, 2015). Three differing perspectives are as follows:

1) "A city can be considered as 'smart' when its investment in human and social capital and in communications infrastructure actively promotes sustainable economic development and a high quality of life, including the wise management of natural resources through participatory government" (Cavada, 2014, p. 4).
2) "Smart cities' is a term denoting the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens" (Cavada, 2014, p.5).

3) “A smart city is a city well-performing in a forward-looking way in these six characteristics (smart economy, smart people, smart governance, smart mobility, smart environment, smart living), built on the ‘smart’ combination of endowments and activities of self-decisive, independent and aware citizens” (Giffinger, 2007, p. 708).

In this case, the city of Hangzhou, China is in the process of further developing as a smart city by creating an interconnected transportation system. This subsystem has proven to decrease the commute time of cars through Hangzhou’s main highways with new technologies like the City Brain project (Lin, 2018). Concurrently, the influx of cars in urban areas has increased and the demand for public parking spaces has developed new challenges for the city.

2.1.2 Breaking Down the Smart City Model

An urban city contains several subsystems that interconnect to form a functioning city. To understand these complex interconnected subsystems, researchers separate the smart city concept into six different core components, called pillars (Ng, 2010). Smart cities typically focus on one or a few of the described pillars (Northcott, 2017).

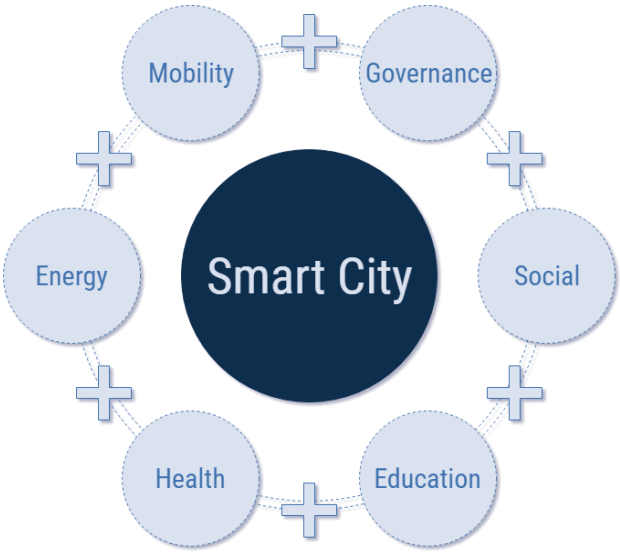

Figure 3: Six pillars of a smart city diagram

The team’s project scope directly relates to the mobility pillar shown in Figure 3 and more specifically how smart parking spaces improve the city’s overall efficiency. With this in mind, this chapter considers the interaction of other pillars and their effects on mobility. In order

to illustrate this interconnection, imagine an efficiency increase in public parking. This could potentially decrease the energy consumed by a car seeking parking during rush hour, thus addressing the energy pillar. Additionally, it could improve overall health by decreasing the accident rate and improving vehicle owners' safety. In the same manner, other pillars would interact in a physical urban city, but the interconnection would be far more complex.

2.1.3 Developed Smart Cities

Depending on the site-specific needs, unique challenges arise that encompass each city's focus on one or more of the smart city pillars. The following two subsections investigate the top smart cities of the world that embody different challenges and develop unique solutions to them (Chaturvedi, 2018).

Barcelona

In 2012, the smart cities team created by the mayor of Barcelona deployed technologies across urban systems which resulted in reduced spending and improved resident's quality of life. This was the city's response to improve Barcelona's infrastructure after the Great Spanish Recession, which hit Spain in 2008. Nowadays, Barcelona has become the hub for Internet of Things (IoT) industry (Adler, 2016). The focus of this smart city is: "promoting sustainable economic development and including the wise management of natural resources through the participatory government" (Cavada, 2014, p. 21). Specific subsystems that the city of Barcelona has developed include digital bus stops, smart parking spaces, smart city lighting, and smart irrigation systems. Fiber optic technology serves as Barcelona's backbone that interconnects all of the city's subsystems. The data that these complex networks gather is open to the citizens to proactively partake in the betterment of the city along with city agencies to use this data to improve city operations (Alder, 2016). The most immediate benefit that the city of Barcelona experienced was its surge from their affected economy to a cost-effective and environmentally focused city.

London

In 2013, the mayor of London launched its Smart London Board (Plautz, 2018). This board undertook current issues with the city, which include the growing pressures on health care,

transport, energy, pollution and traffic congestion (Smartcity, 2017). With this in mind the London Board created a document called the Smart London Plan that depicts smart projects recommendations based on expert observations and study. In this document, the smart city projects of London focus on the community and their interaction with technology (Smart London Board, 2013). One of the most successful smart city projects, London Datastore, allows citizens to freely access the city's database where information and statistics reside. As a result, the community of London developed 450 smartphones apps that use the city's public data. Even though London will soon reevaluate the current Smart London Plan, its smart approach has interconnected the community (Smartcity, 2017).

These international examples demonstrate the various ways that a city can become smart. In the previous subsections, London and Barcelona focused their efforts on two distinct challenges, which are within the pillars of social and governance. These efforts aimed to create an interconnected and more efficient city. All developing smart cities, including Hangzhou, face challenges when implementing new technology into their societies.

2.1.4 Developing Smart Cities in China

There are around one thousand smart cities in the world, and China itself contains around half of these smart cities. Most cities in China are in the developing stage of becoming smart cities; therefore, the majority of these cities focus on a few sub-systems or only one sub-system (Lin, 2018). The following two cities, Shanghai and Hangzhou, focus on the mobility pillar of a smart city. This is significant because the mobility pillar is the core challenge of this project. As seen in the next sections, mobility currently is a big issue in China and these smart cities are focusing their research on finding unique solutions that adapt to each city's infrastructure.

Shanghai

Shanghai, the city with the largest population in China, is a continuously developing smart city. The city focuses on cloud services and smart parking to increase city efficiency. The demand for parking spaces has increased exponentially with the growth of vehicle registration. With this prominent problem rising, the Chinese company Huawei developed a smart parking network throughout the city parking spaces (Lin, 2018). Citizens and users access this system through an app called Shanghai Parking (Chenlei, 2017). In this app, the user can find, book and

pay for a parking space. The direct results witnessed by the city are that this network has eased the frustration of the everyday driver in Shanghai and has reduced manpower costs that included parking supervisors and toll collectors (Lin, 2018). The advances of neighboring cities typically influence smart city developments. The solutions implemented in Shanghai are directly relatable to the needs of Hangzhou.

Hangzhou

Hangzhou, the location of the project team's research, is a newly developed city that is incorporating smart city technologies into many different industries. The city of Hangzhou launched the City Brain project made by tech company Alibaba in 2016 that focuses on the transportation efficiency of the city. The City Brain is a central Artificial intelligence (AI) hub that makes decisions based on various collected sets of data by the cities cameras, sensors and systems. This AI system uses real time sensors and cameras to collect data and analyzes it to manage traffic signals more effectively. The City Brain grants high priority vehicles like ambulances or police cars a faster path through the city intersections by allowing them to pass. With this system, Chinese authorities are capable of detecting traffic violations and taking faster action in various situations (Lin, 2018). Hangzhou is taking a more practical approach by working closely with public services. As a result, the community of Hangzhou has directly interacted with this transformative technology (Chengxi, 2018). The Smart City Research Center of Zhejiang Province has been engaged in the active development of localized smart parking systems that fit the needs of unique characteristic towns in Hangzhou.

2.2 Hangzhou City Background

2.2.1 Current Vehicle Influx

Major cities in China are experiencing an influx of registered vehicles. 24 cities in China have more than two million registered vehicles in total. Based on the national statistics, 2.4 million citizens in Hangzhou own a registered vehicle (Gao, 2018). Hangzhou City Government attempted to relieve the influx by simply building more and more parking lots. The government had already constructed 31,081 parking spots and plans on building 45,000 more by the end of 2018 (Hangzhou City Government, 2018). Land resources, however, are not infinite. The

government will eventually run out of land resources, and alternative solutions are in dire need. Traffic in Hangzhou is largely dependent on the time of the day. Morning commuter traffic lingers throughout the late morning causing major delays in developed urban areas (see Figure 4).

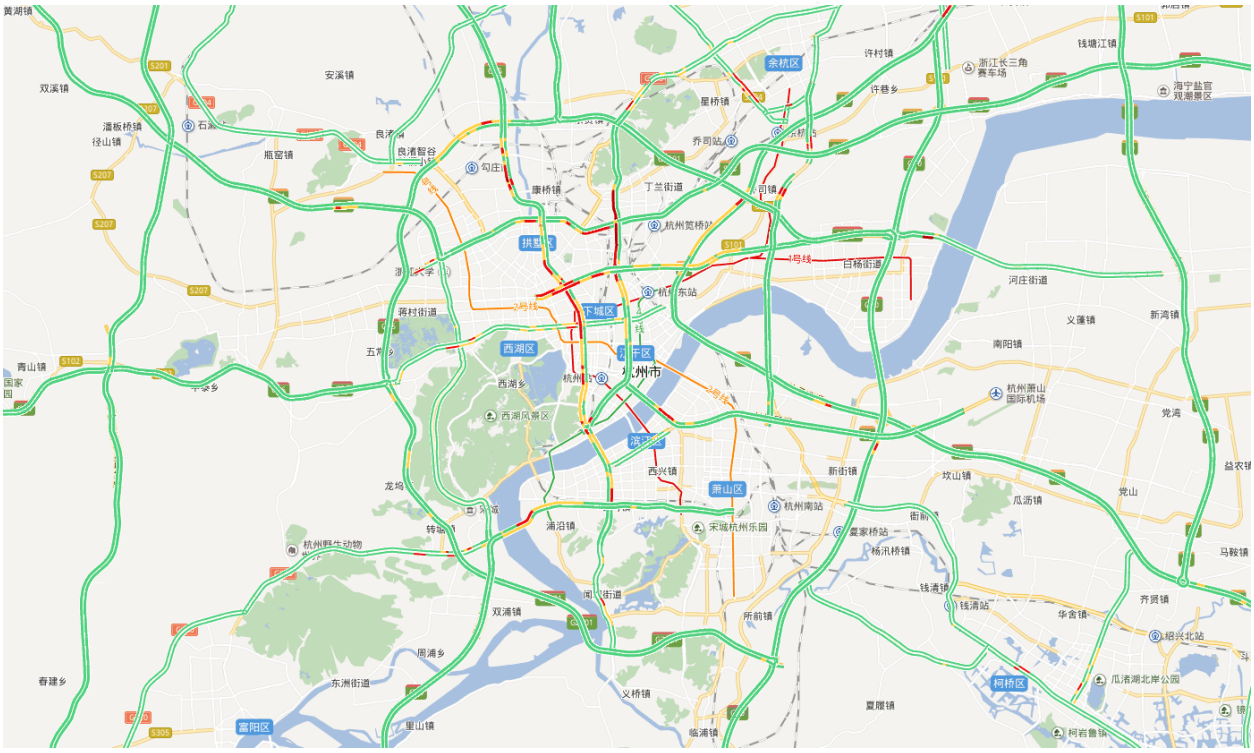

Figure 4: City congestion status in Hangzhou China, 10:00 AM

2.2.2 China's Approach to Parking Management

Known as one of the earliest smart cities in China, Hangzhou developed and implemented a non-contact parking payment system in early 2018. The government collaborated with Alipay, a payment service similar to Paypal in the U.S., to allow drivers to pay their parking fee without involving a security personnel. With the implementation of non-contact payments, the government reported that the traffic efficiency increased by 5% (Hangzhou City Government, 2018). Since these non-contact parking payment systems have yielded an increase in efficiency, the Hangzhou Smart City Research Center now focuses on the overall parking experience. The research center sponsored the project team to investigate solutions to relieve management personnel and improve the overall parking experience for a characteristic town in Hangzhou.

2.2.3 The Concept of a Characteristic Town

The concept of a characteristic town originated in Zhejiang Province. By its definition, a characteristic town is a collection of business and enterprises. While some characteristic towns attract tourism, characteristic towns mostly consist of innovative industries, residency and culture (Ma, 2016). A characteristic town falls into one of three categories: tourism-focused, location-focused and innovation-focused (Sohu, 2017). A tourism-focused characteristic town develops unique cultures or land resources, while a location-focused either acts as an escape from the city or as a convenient transportation location. An innovation-focused, on the other hand, focuses on innovative technology, artistic creativity or high-end manufacturing.

Developing a characteristic town can bring economic benefits to a region, and even more so in an industrialized area of China. The creation of a successful characteristic town can act as the catalyst to trigger a massive influx of characteristic towns in surrounding cities (Sohu , 2017).

2.2.4 The Wide Usage of New Payment Methods

In most major cities in China, mobile applications serve as the primary payment method for everyday purchases. Users can complete payments through a personal quick response (QR) code after authorizing mobile applications such as WeChat Wallet or Alipay to use their bank account information. The use of QR codes in mobile payments has led to the widespread use of QR codes as a convenient method of conducting business sales through non-contact transactions. The popularity of rapid non-contact transactions has forced physical currency to become an outdated form of payment in China. According to Alipay's annual report in 2015, among all the payment methods, the usage of mobile payments took more than 65% of the transactions. By 2017, the number had risen to 82%, with major cities reaching 90% (Sina Tech, 2018). Currently, the two major mobile payment methods are WeChat Wallet and Alipay, with Alipay taking 54% of the mobile payment market and WeChat taking 40% (Xi, 2017). Alipay's headquarters are in Hangzhou, a city where nearly all businesses use non-contact payment methods.

2.3 Current Smart Parking Solutions

2.3.1 Smart Parking Systems

When investigating improvements for any system, it is crucial to understand the different systems currently in use. There are a variety of smart parking systems around the globe, with new system implementations created each year. The five broad categories of a common smart parking system are: Parking Guidance and Information Systems, Transit Based Information Systems, Smart Payment Systems, E-Parking and Automated Parking. Below is the breakdown of the different systems that highlight the unique characteristics of each system.

2.3.2 Parking Guidance and Information Systems (PGIS)

Parking Guidance and Information Systems (PGIS) primarily assist in guiding a driver to their destination and aid them in locating an empty parking space within a facility. In other words, PGIS systems identify unoccupied parking spaces and guide the vehicle to the space. PGIS systems are unique because both decentralized and centralized systems utilize their navigation techniques. Decentralized systems focus on only one parking facility. The centralized systems span across cities or parking facility organizations, which ties all of the facilities into one. Despite the different styles of these systems, the PGIS systems all use some form of GPS and vehicle identification system to achieve their goal (Idris, 2009).

2.3.3 Transit Based Information Systems

Transit based information systems are very similar in their functionality to PGIS systems, however transit-based information systems focus on navigating a driver specifically to park-and-ride facilities. These systems at their core are identical to PGIS systems, however they have an extra layer of information. The extra information consists of local public transportation schedules and traffic information. This real-time information guides the driver to a parking space through calculated computer algorithms. By using this information, the system is able to provide navigation instructions to a parking space that will benefit the vehicle and those surrounding it. This system primarily increases the transit system revenue, but it also increases parking convenience and decreases traffic congestion (Idris, 2009).

2.3.4 Smart Payment Systems

Smart payment systems aim to reduce maintenance and staffing requirements of payment handling by offering payment methods revamped by new technology. While several smart payment systems rely on credit cards, others incorporate automated vehicle identification through RFID technology. A common and well-known smart payment system in the United States is EZPass as seen in Figure 5. EZPass is a system that allows customers to register their vehicle online to receive an RFID tag. This RFID tag receives pings from RFID readers commonly located on highways and in parking facilities. The RFID readers then use this information to charge the driver for the designated fee without the use of personnel. Both managers and consumers enforce payments through email and text communication for easy access. Smart payment systems reduce traffic congestion by improving traditional parking system payment methods and offering customers a more convenient and fast payment method (Leng, 2009). While these payment systems have resulted in reducing traffic congestion, some implementations have also resulted in mandatory passes and penalty fees.

Figure 5: EZPass toll booth in the United States (Cameron, 2015)

2.3.5 E-Parking

Cities, university campuses, and traditional parking complexes commonly implement E-parking. E-parking allows customers to determine the availability of a parking space and/or reserve that space. These systems allow users to send a text message or email to the system in

order to determine the spot availability. Many systems also have an online portal that once logged on, a driver can conveniently register for a space. E-Parking systems often utilize RFID tags to control access by only allowing vehicles to enter the facility with a registered RFID tag. Mobile applications incorporate E-Parking to allow users to reserve parking spaces at the click of a button. The functionality of E-Parking has room for significant growth as these mobile applications could intelligently use their data to restrict parking spaces to their intended audience (such as employee parking and handicap parking) and even offer parking subscriptions for routine customers.

2.3.6 Automated Parking

Automated parking systems primarily aim to physically park the car for the customer. In automated parking systems, computer-controlled mechanisms park each vehicle. The computer is in charge of placing the vehicle in a storage bay and transitioning the cars amongst the facility through various docks and lifts. Like many parking systems, there is great variation in implementations of automated parking. The variation is largely due to many organizations competing to build the next best technology. However, most of the systems utilize robotic parking systems or revolving parking systems to automate the parking process. The perks of automatically parking a customer's car are that the system can best utilize the allocated space, it can excel in locations where expansion is limited, and it offers great vehicle and user safety. The downsides are the social implication of a computer taking complete control of a customer's car and the systems are typically very expensive to construct.

2.3.7 Mobile Applications Potential

The convenience of a mobile application has revolutionized many different everyday services as they now are as easy to access as a user's pocket. In 2009, the founding of Uber attracted people's attention to mobile applications in the automotive industry. Uber is currently worth over $40 billion and if it were a public company as opposed to private, it would be ranked number 367 in the world (Lashinsky, 2017). The sponsor of this project has invested in smart parking research in hopes of creating an app that ties in many systems and features into one convenient app. According to a handbook on the Knovel database, vehicles searching for parking cause an estimated 30% of traffic in urban settings (Vesco, 2015). The goal is to optimize this

process by creating a centralized system that navigates a customer to an optimal parking spot, helps determine the parked car's location within a crowded area once parked, and automatically charges the customer electronically. The app's focus is to tie in many smart parking systems that filter the proper data to the app needed to achieve the overall goal. Simulations conducted by researchers in other parts of the globe indicate that a smart parking system of this kind could increase parking space utilization by 10-20%. This in turn would lower parking congestion and offer higher revenues for parking operators (Vesco, 2015). The project sponsor has previously researched mobile applications which mitigate city congestion, improve vehicle access data, and reduce management personnel. The scope of the apps are limited to specific regions, yet there is ongoing research that reveals the potential for a future nationwide solution.

2.3.8 The Development of Smart Parking Systems in China

With such a large influx of registered vehicles in China, there have been numerous attempts at lessening city congestion and creating more efficient localized parking management systems. The current issue at hand in Hangzhou is that the current smart parking system implementations cannot keep up with the rapid development of the city. The general parking infrastructure varies greatly across complexes, as each system design supports its unique location.

While the need for unique parking systems limits the feasibility for a citywide parking management system, a handful of mobile applications have been able to detect which complexes have available parking in a convenient platform for the public. Currently there are a handful of Chinese apps in use (U-parking, ETCP, etc.), which lessen the load of city congestion and direct drivers to open spots (Xuequan, 2018). While this solution is adequate at creating a more efficient parking direction system, these complexes have not fully utilized the full potential of mobile applications. The truth of the matter is that even with the implementation of mobile devices in smart parking, Hangzhou is simply too large to create a universal parking solution. Rather, researchers have been putting efforts into developing localized improvements to parking solutions in hope of creating a higher net city efficiency in parking.

2.3.9 Opposing Factor to Smart Parking Development

Another notable obstacle to the efforts made through smart parking solutions is the social formalities in China with regards to parking. Considering the Chinese government's role in dictating the fares for individual parking garages, the public may view the prices as inflated or disproportional. Like in most developed cities, free parking spaces are highly valued in China. In short, there is a significant gap between the prices of parking solutions in China. For the most part, underground parking complexes greatly differ in price from their above ground alternatives. The above ground alternative in Hangzhou are mostly parking complexes and meter enforced street parking. The government requires expensive fairs for developed parking lots, and leaves free parking on streets, making the public far less inclined to pay for parking. While the Hangzhou government has made efforts to encourage the use of land to develop new parking complexes in 2014, there is a need for significant efforts to fully utilize the smart parking technologies that are available (Yang & Huang, 2017). In order for current and future smart parking technologies to create an impact on city efficiency, these new technologies must be socially acceptable and continually used by the city occupants. Improvements to both the hardware and software systems in place have the potential to create a socially accepted parking solution.

2.4 Supporting Smart Parking Technologies

The application of information systems applied to smart parking has developed far past the simple integration of just RFID technology. This project offers a solution that incorporates RFID with additional sensing technologies developed in the smart parking industry. Considering smart parking is a relatively new concept that is constantly evolving to meet an ever-growing volume of vehicles, there are various sensing methods currently applied in parking complexes.

2.4.1 Optical Character Recognition Cameras

Optical Character Recognition, or OCR, is one of the most common types of vehicle identification technologies applied in many facets of the automotive industry. These small cameras automate highway tolls, create a streamlined entrance procedure, and improve vehicle localization methods within parking complexes. In its simplest form, OCR cameras capture

images of customer vehicle license plates, followed by a comparison and storing process of the images. The data stored in each image file allows the system to compute parking fees, identify a vehicle owner's information, and keep track of the vehicle throughout the complex.

2.4.2 Infrared Sensor Systems

A far simpler applied vehicle management technique is the use of infrared sensors throughout smart parking complexes. Infrared sensors utilize low frequency light as a proximity sensor to determine if a vehicle is occupying a parking spot. Typically, these sensors are above or below a parking space to gauge the distance in-between the sensor and ground (or ceiling). For instance, a sensor pointing down will output a different value when a spot is vacant than when occupied, as the distance that the infrared light travels will change. This discrete data translates to a localized system to keep track of available parking.

2.4.3 Bluetooth Communication Integration

Bluetooth technology has been a newly explored solution in the smart parking industry. Companies such as Parkifi have been widely successful at implementing low cost, low energy sensing modules in both parking complexes and citywide management systems. Bluetooth typically uses 2.45 gigahertz frequency in application, and is a simple communication protocol for integrating smartphone connectivity to a sensing system. In most parking applications, the Bluetooth modules are small surface sensors that relay information from the sensor to a mobile device. This information provides a system with specific parking space vacancies that assists in calculating overall parking availability. While Bluetooth on its own is unable to detect a motor vehicle, combining Bluetooth with other sensing technologies enables a consumer to manually mark a spot as occupied. The integration of Bluetooth in smart parking allows for wireless communication between parking spaces and ultimately reduces the need for physical wire connections throughout parking complexes.

2.4.4 Electromagnetic Field Sensors

When evaluating most on ground sensing modules, one of the most prevalent types of technologies used in smart parking complexes is electromagnetic sensing. These small sensors have the capacity for above and below ground applications as a method of checking parking

space availability. The sensors work by tracking changes in magnetic fields, using earth's natural levels as a baseline. When a vehicle is present in a spot, the magnetic fields registered by the sensor are far different from that when the spot is empty. This altered information transfers to a localized system which keeps track of the available parking in a complex.

While most current parking complexes in Hangzhou use RFID as the primary form of vehicle identification and management, there is significant room for improvement in the overall efficiency of the system. Applying as little as one, or many additional technologies enables smart parking system configurations to minimize the need for personnel, and increase the overall logistics of parking within a characteristic town.

2.5 RFID Hardware Solutions

2.5.1 RFID High Level Overview

To understand the basic structure of RFID hardware, it is important to first discuss the main components of a typical network. In its simplest form, an RFID network consists of a reader and distributed tags (see Figure 6). The reader module itself is a powered device which emits electromagnetic waves which vary in frequency depending on location and application. Subsequently, the tags contain owner specific information distributed by the system managers. Vehicle identification and management within parking complexes typically use RFID technology as the form of verification. The RFID tag acts as a unique identifier for each customer and assists in the payment process by allowing systems to charge fees based on the customer's identification.

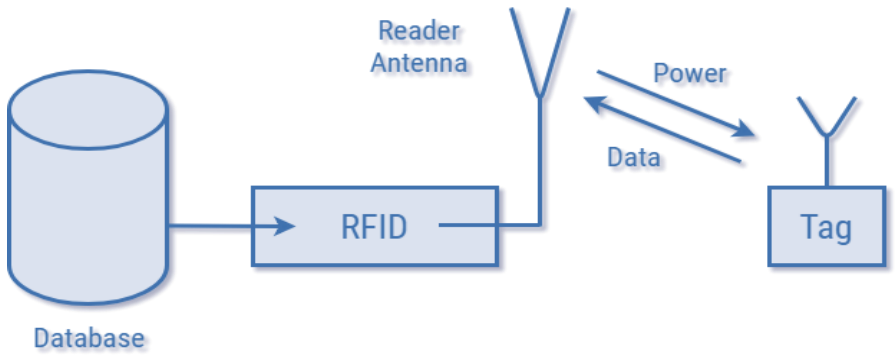

Figure 6: High level RFID system overview (Boularess, Rmili, Aguili & Tedjini, 2015)

2.5.2 Passive, Active, and Semi-Active RFID

The hardware developed to support modern RFID infrastructure is passive, active, or semi-active technology. Identifying RFID tags as either passive or active depends on the presence of an on-board power source and related transceiver. In a typical passive RFID tag, waves emitted by the scanner hit the metal foil antenna within the tag. These electromagnetic waves generate sufficient current to power a small identifier chip and transmit the same waves back to the reader at an altered frequency. Active and semi-active tags employ this same principle, but with the implementation of a powered transceiver. By amplifying the reader's supplied signal, active tags allow for operation "regardless of the presence of an RFID reader in proximity and provide greater operating range compared to passive RFID tags" (Tsiropoulou, Baras, Papavassiliou & Sinha, 2017, p.34). The tag's overall role in the system determines the distinction between semi-active and active RFID tags. An active tag, sometimes called a beacon, emits its information as an electromagnetic wave for the system scanner to receive. These devices require significantly more power, as they typically emit a signal periodically (some as often as every 3-5 seconds). A semi-active tag only emits information when it receives a signal from the system scanner. Semi-active tags, often known as transponders, act as a beacon when in proximity of the scanner.

2.5.3 Applications of Specific RFID Technologies

The application of these varying types of RFID hardware is dependent on the duration of ownership for each tag, overall system budget, and level of necessary security. While active and semi-active RFID tags are clearly a superior hardware solution in terms of wireless connectivity, it is important to consider the additional costs. The need for an onboard power source and active transceiver means that each tag comes with a significantly higher price tag in comparison to passive tags. Consequently, in applications with little necessary security or temporary ownership of each tag, passive systems are typically the more economical solution. The trade-offs to using a passive RFID tag lie in the simplicity of the hardware. Depending on the format and frequency, professionals claim that passive tags have "no protection of data, no privacy, [and] everything is in the clear" (Brown & Fox, 2013, p.5). It is common knowledge that passive tags are vulnerable to manipulation, as with all RFID technology.

2.5.4 RFID Hardware in Smart Parking Systems

The scope of the team's research involved studying the implementation of additional information technologies in tandem with the RFID hardware present in many current smart parking solutions. Understanding what technologies will be beneficial when used alongside RFID requires the background knowledge of RFID's use in parking management. As discussed with the project sponsor, a high percentage of parking complexes in China utilize RFID and similar technologies.

The RFID systems used in parking solutions do not differ greatly between complexes. The modern information management system includes both active and passive technology in RFID smart parking systems. The most common RFID gating systems utilize readers placed at parking gates, where tenants scan their passive tags (typically in card form). Additionally, there are less common passive tag systems which utilized ultra-high frequency windshield tags and long-range scanners at each entry gate. "The longer read range of passive ultra-high frequency (UHF) enable[s] the system to automatically interrogate the tag on the windshield" which streamlines the parking queue by removing the need for a tenant to roll down their window and scan a tag (Roberti, 2014, p.1). The use of active tags in smart parking management systems has recently become more common in identifying and quantifying the available spaces within a parking complex. Utilizing transponders and beacons for their long-range capabilities has opened the doors to new forms of tag positioning within a garage, allowing for more accurate vehicle management and navigation.

2.6 RFID Infrastructure

2.6.1 RFID Host Computer

In a modern RFID parking system, there is typically a host computer positioned within the facility near the RFID readers. A queue processed by the host computer organizes and positions information sent by the RFID readers. By performing these functions, the host computer serves as a monitor for ensuring that the reader is functioning properly, securely and contains up-to-date instructions (Bai, 2012). Through monitoring the RFID devices, the host computer controls errors and facilitates a successful operation when a reader contacts an RFID tag. In order to properly filter collected data, the host computer requires compatible middleware to intelligently process the data from a smart parking system.

2.6.2 Middleware

Middleware is “the software that connects network-based requests generated by a client to the back-end data the client is requesting” (Rouse, 2017, p.1). In regard to RFID systems, middleware controls communication between an enterprise application and the RFID readers. The middleware is responsible for controlling the data by collecting, filtering, and organizing it. The RFID reader and host computer typically have installed middleware software. In certain situations, both devices have installed software. While the host computer offers raw processing power for a RFID system, the middleware provides more features tailored to the needs of the specific system. For example, if a vehicle was supposed to have access between 9am-9pm, at 10pm the system should decline the vehicles request to access the parking complex. Software engineers program middleware to meet these logic requirements.

2.7 Utilizing RFID Technology

The smart city of Hangzhou has already implemented the City Brain which interconnects the city’s physical subsystems and enables the exchange of data (Lin, 2018). This interconnectedness of physical networks is a crucial factor of the smart city model (Glasmeier, 2015). Therefore, a system that incorporates the Internet of Things (IoT) provides an effective mechanism for tracking physical objects and along with RFID it can greatly improve the transparency of a system. Thus, the idea of having an architecture for RFID and IoT surges given that, “networked services that speak about things, rather than services that reside inside the objects themselves” (Fabian, 2010, p.1). IoT, along with RFID, enables data to be stored in an easily shareable local database. The RFID reader retrieves data with a specific Electronic Product Code (EPC) from a location where the server can connect with the RFID tag. EPC is a unique number given to the RFID tag that enables compatible systems to retrieve the data from the local server (Fabian, 2010). The capabilities for a system that uses IoT with RFID are numerous, and if researchers implement them correctly, they can improve the system overall. Furthermore, specific cities or regions require systems tailored to their needs, as there are specific laws and regulations that affect integrated RFID technology in any system.

2.8 Local Regulations

2.8.1 Local Laws Regarding Parking

While advanced technology has made an impact on smart parking systems, local laws and regulations have a large restriction on these systems' implementation. The local laws determine the location and technology used in a new smart parking system. These laws do not affect just the technologies of parking systems, but they also affect general parking as well. Specifically, The Road Traffic Safety Law of the People's Republic of China issued by the Security of the People's Republic of China (MPS) stated three laws regarding illegal parking: No. 33, No. 56 and No.93.

China's law No.33 requires newfound public service buildings, shopping areas, residential areas and massive structures to build parking lots. If the parking lot does not offer sufficient parking spots, landowners must expand or rebuild as soon as possible. Additionally, the government prohibits shutting down or modifying a parking lot. The government can assign parking spots on the streets as long as it still satisfies the need of traffic fluidity.

Laws No.56 and No.93 put forth regulations regarding illegal parking. Law No.33 states that motor vehicles must park in dedicated areas. Additionally, there are laws against parking a motor vehicle on public sidewalks. If a driver parks their vehicle illegally, or if they refuse to relocate their illegally parked vehicle, they are subject to a fine no less than 20 CNY and no more than 200 CNY (National People's Congress of the PRC, 2016).

These laws specifically protect street parking within China, yet do not explicitly cover parking complexes. Smart parking developments must consider security measures, and ultimately encourage legal parking within the city. Efficient use of available parking spots is a primary factor in the direct relationship between legal parking and city-wide parking management.

2.8.2 Local Laws Regarding RFID Technology and Data

The Ministry of Industry and Information Technology of the People's Republic of China and the State Radio Regulation of China issued two regulation laws regarding proper and permitted usage of radio frequencies. Both regulations claim that the radio frequency must fall under categories regulated by the ministry; a radio frequency expert must be present in the project development team and the production may not interfere with other legal radio

frequencies' usage (State Radio Regulation of China, 2016). Setting up and using radio frequency without gaining permissions from the ministry may result in a fine of 50,000 to 200,000 CNY (Ministry of Industry and Information Technology of the PRC, 2017). However, the usage of short-distance radio frequencies (such as those RFID uses), do not require gaining any permissions.

2.9 Characteristics of a Solution

The project team's goal was to create an efficient smart parking solution for a characteristic town in Hangzhou, China. The project sponsor requested a recommended smart parking solution that simplifies when broken down into individual characteristics. She presented to the project team the characteristics of a smart parking system. The sections below outline the characteristics that guided the final proposed smart parking system.

2.9.1 Payment Methods

Smart parking complexes use various types of payment methods, dependent on the societal norms of a specific area. Today's most common parking payment systems include payment by phone, payment to a human or automated toll booth, payment by printed toll tickets or a combination of these services. In a parking complex the payment methods are the main form of interaction between the infrastructure and the consumer. The payment methods of smart parking systems aim to organize and administer consumer parking fees conveniently for their customers. A solution that incorporates multiple payment options for consumers allows for a larger audience of potential customers. With this in mind, a convenient and easy to use payment method that adapts to the consumer is ideal to the success of the final proposed solution.

2.9.2 Localization Technique

Localization techniques widely used in robotics have spread into the area of smart parking. Localization within current smart parking is rare, as it was often a large expense to integrate sensing systems into past physical infrastructures. As RFID and similar technologies have become more common, and naturally less expensive, information management systems have become more prevalent in smart parking systems. The ability to detect the approximate location of a specific vehicle within a parking complex allows for more efficient parking space

management and vehicle navigation. The localization technique works effectively in conjunction with a navigation interface and supporting sensing technologies.

2.9.3 Reservation Technique

Many parking complexes, even those not considered ‘smart’, offer methods to reserve parking spaces. Parking space reservation can be extremely convenient for consumers, while also offering additional options to providers such as increased revenue through exclusive parking spaces, privilege restrictions, and improved parking organization. Many modern parking complexes offer parking spaces exclusive to public customers, private residents, in addition to specific spots designated for vehicles with handicap or electric vehicle license plates. Allotting spaces for specific customers enables the inclusion of all customer demographic needs. Smart parking systems require a technique to identify a vehicle as being eligible for a parking spot that only certain customers may access. There are many different reservation techniques dependent on the supporting complex infrastructure, thus making this an important consideration of the final solution to fit the characteristic town’s unique needs.

2.9.4 Device and Equipment Location

The final proposed smart parking system has various devices and equipment that communicate to increase overall system efficiency. The project sponsor expressed interest in the device and equipment location pertaining to RFID tags, host computers, and sensing technologies. The project team qualifies the location of the necessary system equipment to adhere to the proposed system operation flow. RFID tags are a crucial characteristic of the final solution, as certain materials and distances can restrict the data transmission. Additionally, the host computer location is important to the final solution as the host computer processes the recorded complex data for the entire smart parking system. An efficient and effective system requires the strategic placement of all equipment in order to properly obtain and process the necessary data.

2.9.5 Vacancy Identification

Most parking complexes nowadays use LEDs and screens to display the vacant spots. Vacancy identification is the process of identifying the availability of parking spaces within a

parking complex. The available parking space information allows consumers to effectively navigate the parking complex while searching for an empty parking space. As simple as it may seem, adding a LED or screen system that displays parking space vacancy can make searching for a spot in a congested complex largely convenient. This system characteristic primarily adds convenience to the parking experience, ultimately allowing for increased parking efficiency. Vacancy identification can be a powerful feature if customers use it correctly in tandem with other smart parking features.

2.9.6 Navigation Interface and Technology

Due to the high population of China's cities such as Hangzhou, the resulting traffic congestion impairs vehicle owners' ability to find available parking and locate their parked vehicle. This impairment is a focus area for smart parking solutions, as the ability to effectively locate available parking and parked vehicles is very convenient for vehicle owners. Current smart parking systems offer various navigation technologies that all utilize different technologies to navigate a vehicle to available parking and locate a parked vehicle. This characteristic of a system consists of two parts: the navigation technology and the interface. The navigation technology is the method used to sense available parking spaces and locate a parked vehicle based on its vehicle and owner data. The navigation interface is a user's visual tool to view information displaying available parking spaces and their vehicle location once parked. Typically, this interface needs to be convenient, otherwise the users will not use it. The final proposed smart parking solution has navigation technology and an interface that effectively track available parking spaces, locate a parked vehicle, and display the necessary information to a user; all while working in tandem with other parts of the system.

2.10 Summary

The city of Hangzhou's rapid increase in vehicle registration has resulted in an insufficient amount of available parking, exposing an inefficient parking management system. The current parking system is outdated in relation to today's technology, which has led to the potential for a smart parking system that increases city efficiency. The shortcomings of the current systems have resulted in the increased traffic congestion, revealing the need for modern parking technology across the city. Countless developers across the globe have developed smart

parking solutions that have successfully increased city efficiency. The Smart City Research Center of Zhejiang Province is in the process of researching potential improvements to Hangzhou's current system. Further developments in Hangzhou's smart parking systems could improve vehicle safety and access data, while reducing management personnel; ultimately mitigating traffic congestion and improving everyday life.

Chapter 3: Methodology

This project focused on suggesting a recommended smart parking solution for a characteristic town in Hangzhou, China by studying modern technologies that address the shortcomings of current systems. With the help of the Smart City Research Center of Zhejiang Province, the project team explored the needs of relevant consumers and providers to guide research towards feasible applications of smart technologies.

The final project deliverables are a written report and presentation that propose a future smart parking system that could improve vehicle safety, vehicle access data, and ultimately traffic efficiency through the implementation of improved technologies within a characteristic town.

Figure 7 presents the organization of the team's process for analyzing data and conducting research while in Hangzhou. The following chapter consists of sections outlining each individual objective and the necessary methods to reach the objective goal. This chapter concludes with an explanation of how each individual objective leads to the development of the final project goal.

Figure 7: Smart Cities methodology flowchart

3.1 Objective One: Study Hangzhou's Current Smart Parking Systems

In order to accurately approach the project goal of developing a smart parking solution for a characteristic town in Hangzhou, it was important to have a concrete understanding of the current technology applied within the city. With a proper foundation of knowledge pertaining to the current systems in place, and needs of the applicable parties, the team developed recommendations to assist the future design of a feasible and effective smart parking system.

The team first performed naturalistic observations in Hangzhou that targeted the current system characteristics and their consumer interactions. Additionally, the project team consulted with relevant stakeholders such as industry experts, customers, and developers in the smart parking industry. The team then drew considerations from the data to guide the research and development of a future smart parking solution. Figure 8 displays the process that the team conducted to understand Hangzhou's current smart parking systems.

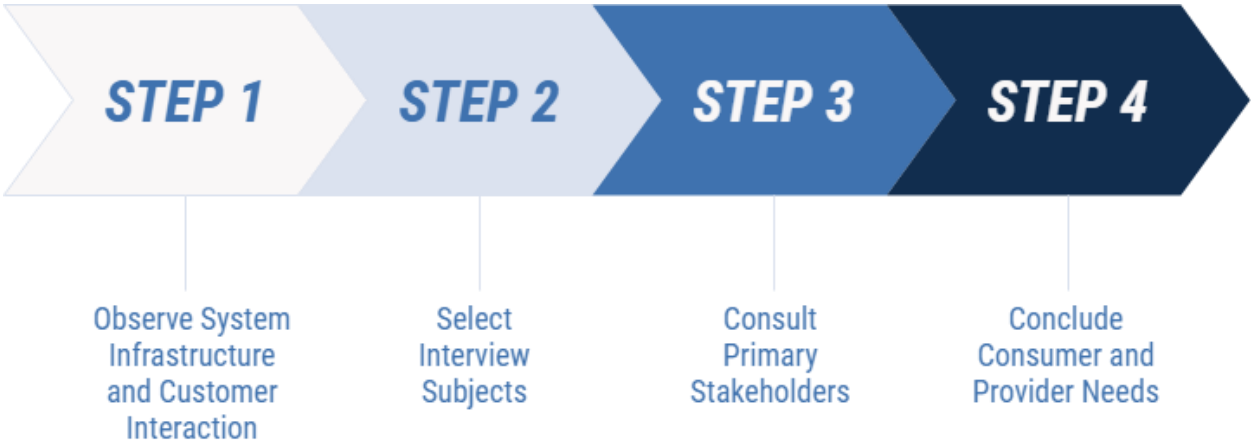

Figure 8: Smart Cities process of studying existing smart parking systems in Hangzhou

3.1.1 Observe System Infrastructure and Customer Interaction

The team performed naturalistic observations to identify current technical management systems, vehicle navigation techniques, and the interaction between consumers and parking systems. Through these observations, the team gained a better understanding of the needs of Hangzhou vehicle owners. Figure 9 displays a map of Hangzhou with the locations that the team conducted observational research. The team chose the locations based on their diverse applied technologies, user demographics, and similarities to characteristic towns. The project team

believed observing the current smart parking systems' real life applications would provide data to guide research on a future smart parking system for the characteristic town.

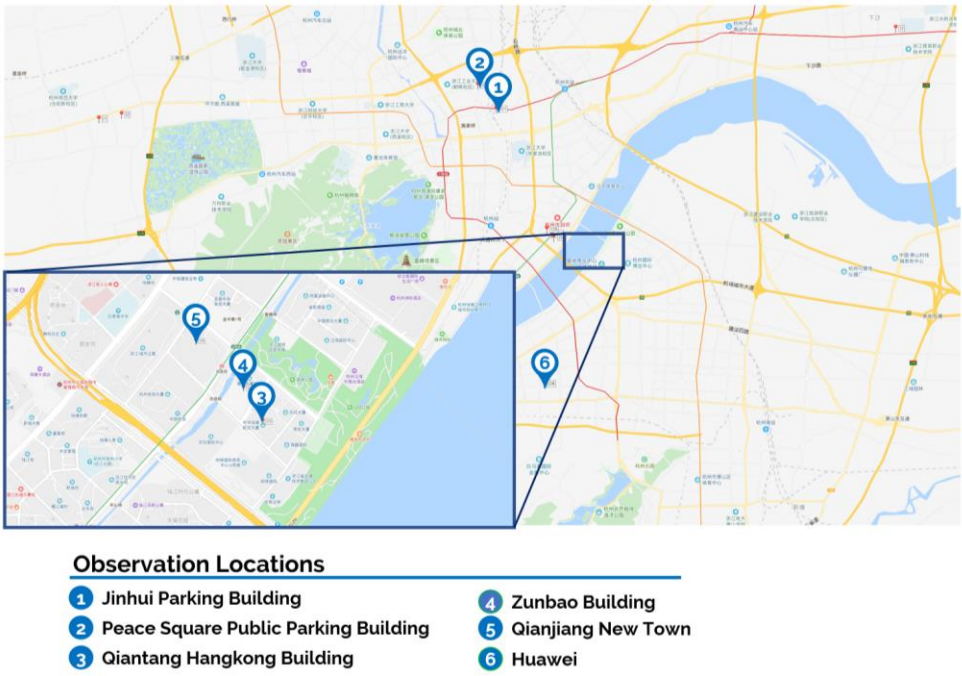

Figure 9: Map of conducted parking complex observation locations in Hangzhou

During this observation period, the team noted the technology applied in the garage, the associated equipment, and overall system framework. These technical details allowed the team to identify the most common system characteristics and assess their effectiveness in Hangzhou's smart parking complexes. Appendix I displays the organizational chart the project team used to record notable system details, and corresponding customer interactions while observing the six parking complexes. The team completed individual charts for each observation location by recording important information for each system characteristic. The team and one Hangzhou Dianzi University (HDU) student per location conducted the observation visits. While at the parking complex, one Worcester Polytechnic Institute (WPI) student recorded the observation findings, while the other participants focused on evaluating the parking system.

3.1.2 Select Stakeholders for Consultation

This section contains sub-sections representative of the key stakeholders in the development of smart parking, and the team's rationale in selecting the groups. The second phase

of this investigation was to interview or survey the project stakeholders to understand the progress of the development of smart parking. The following groups are significant in the ongoing development of smart parking solutions capable of supporting an increasing number of registered vehicles in Hangzhou.

Industry Experts

Stakeholders relevant to the Internet of Things and smart parking solutions provided information which allowed the team to be cognizant of possible technological improvements to current smart parking systems. Companies such as PShare Company and Alibaba have significant resources invested in the development of Internet of Things technologies and smart parking solutions. Alibaba is an industry leader working on future non-contact payment methods for smart cities. Employees at PShare Company have developed innovative modular parking space locks that improve parking complex management. By consulting with these experts, the team obtained suggestions for future smart parking systems and the direction of smart technology research. The team was fortunate to have the project sponsor work alongside the team to interview the industry experts.

Smart Parking Customers

Relevant consumers to this project were people who use smart parking complexes equivalent to that of the characteristic town. These customers were primarily employees and visitors who routinely parked their vehicles in smart parking complexes around Hangzhou. The opinions of these subjects provided firsthand information on the shortcomings of current systems which affected their daily life. Taking into account the opinions of both the residents and local employees allowed the team to develop a solution which aims to address the needs of all relevant parties. Gauging the public opinion on the features and improvements that appealed to the average customer allowed the team to connect proposed solutions to the social aspect of smart parking integration.

Graduate Research Students at Hangzhou Dianzi University

The team was fortunate to have the opportunity to develop a working relationship with the Smart City Research Center of Zhejiang Province. While the research performed by these

students focused on technical developments, the underlying challenges addressed by the research students were relevant to this project team's overall goals. The team worked alongside the project sponsor to administer interview questions to two selected graduate students. Consulting these research students aimed to provide insight on the smart parking solutions that they believed had the most potential in future parking developments.

3.1.3 Consult Primary Stakeholders

Industry Interviews

The team participated in six sponsor facilitated interviews with industry experts and graduate research students in Hangzhou, China. During these interviews the team obtained information pertinent to the effectiveness of smart technology currently used in China's parking complexes, along with the feasibility of additional sensing technologies. In addition, the project team asked questions regarding potential future technologies relevant to the project, as the interviewed companies focused on many technologies that were not limited to current smart parking methods. The team's interviews followed a semi-concrete structure in which a set of six set questions which guided further open discussions. This allowed the project team to obtain a wide array of relevant information to the project. Appendix E outlines the interview questions that guided discussions with IoT experts.

Public Surveying

The team decided to administer a brief survey in order to gauge customer experience and overall satisfaction levels. A convenience sample represented a localized opinion of seventeen smart parking customers from four different parking complexes around Hangzhou. The team took into account that a portion of the survey demographics should be both employees and visitors of similar characteristic towns. The project team carefully chose survey locations displayed in Figure 10 based on their surrounding businesses and residential areas, as well as their current smart parking systems. The team offered simple research questions to gauge the consumer needs of the frequent users of the parking complex (displayed in Appendix C & D). Considering the project scope consists of industrialized areas, the team decided to survey past the 5:00 pm workday in order to interview workers who were leaving their place of employment.

This strategy produced a widespread set of opinions, including those of professionals who used smart parking complexes.

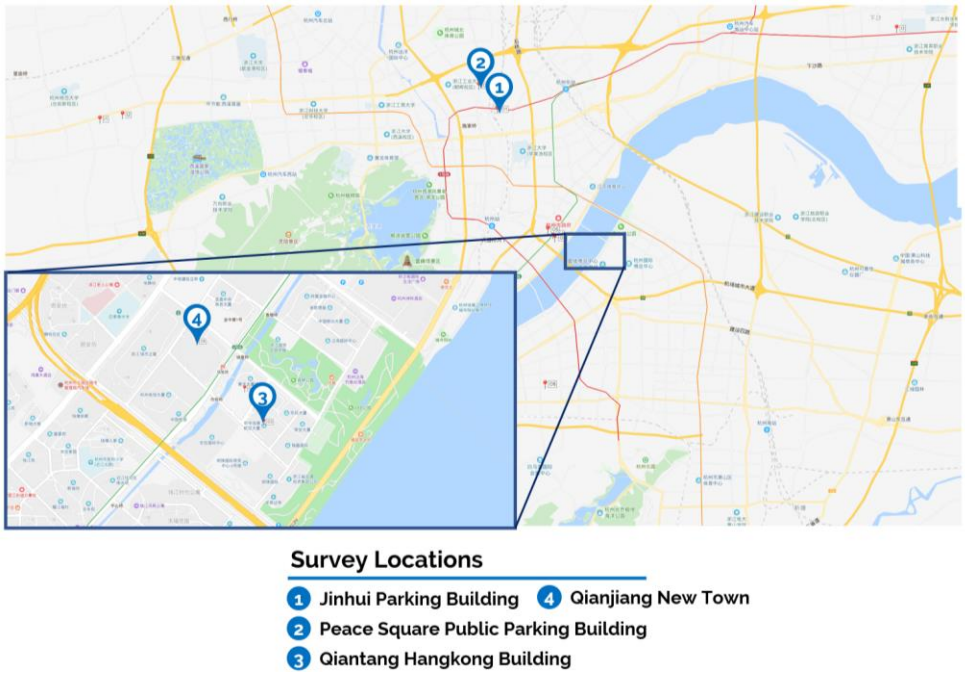

Figure 10: Map of parking complex survey locations in Hangzhou

The format of the surveying period was concrete; in other words, the team asked questions that were identical between survey subjects. With the help of undergraduate student "buddies" from Hangzhou Dianzi University (HDU), the team members approached and consulted customers leaving or entering the respective parking complexes. The team administered the survey subjects printed copies of survey questions. The Chinese HDU students facilitated these surveys, as most survey respondents did not speak English. The project team recorded the survey responses in Chinese, and later translated them to English for evaluation. The team did not record the survey subjects' personal information as the surveys were confidential and required no consent. The administered surveys targeted the customer's satisfaction and experience for the parking complex at which the survey was distributed. The project team transferred the data recorded from a hard copy into a simple Microsoft Excel table for further analysis. The following are some of the most important questions included in the surveys:

1. Do you think the technology used in the parking lot is sufficient?

This question aimed to gauge the customer opinion of current smart parking technology in Hangzhou.

2. Have you experienced any issues when parking in this complex?
   This question targeted the issues experienced by current customers.
3. Please rate how difficult it is to find your parked vehicle in this complex.
   As noted previously, one of the largest issues with parking in China's densely populated cities is that it is very difficult to find a parked car. This question gauges the effectiveness of the navigation technology used in the parking complex.

3.1.4 Infer Consumer and Provider Needs

The team leveraged responses to customer surveys and expert interviews with respective observation findings to infer consumer and provider needs. During the observation period the team recorded characteristics of the current systems in Hangzhou to later gauge system effectiveness using customer responses. The team treated surveys and interviews as two separate sources of data, along with different analysis methods. The team grouped survey responses and highlighted them to present trends between the seventeen subjects, as not all questions presented distinct trends. The project team recorded interview responses as transcripts and color coded the responses to identify recurring themes.

Following the completion of the seventeen surveys, the team recorded the subject responses in an Excel sheet seen in Appendix L. To further analyze the data recorded during the surveying period, the team used the Excel sheet to present the entirety of the data together and show apparent trends. By placing borders around similar questions, the team highlighted trends in the responses of subjects across all four surveying locations. Anticipating that not all questions would present legitimate trends, the team completed the task of outlining questions with apparent trends upon completion of all of the surveys. The team's approach to recognizing trends involved looking over all seventeen surveys and identifying commonalities between all subjects, as well as similarities of responses at each individual parking complex.

Additionally, the team used an alternate coding technique to organize interview responses. Using the color codes shown in Table 1, the team color-annotated transcriptions of the interview responses. This allowed for easier analysis of each interview transcript, by taking into account the relevant theme to the response. While this technique does not necessarily quantify

the recurring themes, the team was able to take note of the main discussion points from each response. Table 2 organizes the themes present in the recorded interview results. The team identified correlations seen in the table which allowed for analysis of present trends. Consequently, the analysis process counted the occurrences of all "themes" of both survey and interview results. These recurring themes in both interviews and surveys, were relevant to the team's considerations when engineering the final recommendation.

Availability……...GREEN
Convenience……..……YELLOW
Hardware Technology……...……ORANGE
Payment Method……..……PINK
Price……BLUE
Safety……...……..…PURPLE
Social Idea…….…..……LIGHT GREEN
Software Technology……..…LIGHT BLUE

Table 1: Coding Themes

Interview Coding Table							
	Alibaba	Hangzhou Pshare Tech Co.				Researcher & Graduate Students	
Themes	Shuai Li and Li Yuan	Jie Lu	Zhanyi Shi	Weijie Li	Hongcheng Shen	Min Shi & Ruiqing Qiu	Theme Total:
Availability	2	1	1	1	2	1	8
Convenience	1	1	0	0	1	0	3
Hardware Technology	0	4	4	4	1	3	16
Payment Method	2	0	0	0	0	0	2
Price	0	0	0	0	0	2	2
Safety	0	1	0	1	0	0	2
Social Idea	4	1	2	0	3	4	14
Software Technology	0	0	0	1	0	2	3
Interviewee Total:	9	8	7	7	7	12	

Table 2: Interview coding table for industry experts and researchers & graduate students

3.2 Objective Two: Evaluate Potential Smart Parking Solutions

Taking into account the needs of both the consumers and providers found in objective one, the team determined potential solutions to address current parking challenges in the characteristic town. A majority of the initial research began with researching potential solution characteristics which pertained to a system framework and the associated technologies. This portion of the project aimed to qualify solution characteristics and analyze their feasibility for the characteristic town. A SWOT analysis compared and evaluated the different technologies and their applications.

3.2.1 Research System Elements

After identifying consumer and provider needs in objective one, the team researched potential improvements to the smart parking system that fit the identified needs. The team began researching improvements by evaluating the current parking systems in the six observation sites from objective one. The examinations performed in objective one allowed the team to record the visible hardware of these smart parking systems. The team researched the current technologies witnessed in observations and discussed in interviews. The research aimed to identify key characteristics of the witnessed technologies and alternative technologies that are more feasible for the IoT town.

In order to obtain examples of different technologies applied in smart parking outside of Hangzhou, the team researched smart parking technologies used in United States of America. In addition, the research considered Shanghai's current smart parking systems as supporting evidence of technologies feasible for Hangzhou. Shanghai is a much larger and more developed Chinese city compared to Hangzhou. Due to Shanghai's size, there is a constant trend of innovative technologies tested and deployed within the city. Many newly developed cities such as Hangzhou implement very similar technologies. The research hypothesis here was that successful solutions in Shanghai could have applications for the characteristic towns in Hangzhou.

In addition to the research of different technologies, the team focused on specific defining characteristics of a future smart parking system. The key characteristics which the team researched are as follows:

- Payment method
- Reservation technique
- Device and equipment location
- RFID tag type
- Vacancy identification
- Navigation interface and technology

The project sponsor indicated in an initial sponsor meeting that these characteristics were vital to the feasibility of the final recommendations. The team leveraged the research on each characteristic and its corresponding technologies to construct a flowchart that displayed the recommended system's framework, as described in section 3.3.1.

3.2.2 Compare & Analyze Feasibility of Researched Solutions

The team followed preliminary research with SWOT analyses to compare the different technologies and their ability to satisfy the developed consumer and provider needs. This analysis technique aimed to identify technologies and system characteristics that best fit the characteristic town. A SWOT analysis organizes strengths, weaknesses, opportunities, and threats of various options to gauge their potential effectiveness. Furthermore, a key aspect of the SWOT analysis is the breakdown of the internal and external factors that directly or indirectly affect the solutions. By considering both internal and external factors, the team gauged the feasibility of specific system elements for the IoT town. Figure 11 displays the SWOT analysis format the team used.

Figure 11: SWOT analysis table

3.3 Objective Three: Present Recommendations and Report Findings to Sponsor

The project sponsor requested final recommendations of a smart parking solution for the IoT town. The project team constructed flow charts and diagrams which illustrate a high-level overview of the smart parking system.

3.3.1 Determine the Recommended Solution

Through coding and trend analysis each individual element of the recommended solution satisfied the previously inferred stakeholder needs. The project team's research and respective SWOT analyses qualified the recommendations and their assumed feasibility. An efficient smart parking system's functionality goal is for each system element to work fluidly with its corresponding system counterparts. In order to construct a smart parking solution that interconnects various technologies, the system elements must be complementary of each other. The team supported the recommended system through explanations and visuals that depict the role of each chosen characteristic in the final system.

3.4 Summary

This project's mission was to suggest a recommended smart parking solution for the IoT town of Hangzhou, China by studying modern technologies and smart parking system characteristics. To accomplish this goal, the team performed observations, surveys, and interviews in order to develop an understanding of current smart parking systems and their challenges. The data analyzed provided insight to the needs of consumers and providers of parking solutions in Hangzhou. The needs of both parties influenced the research of smart parking solutions for a targeted area in Hangzhou. The team furthered preliminary research by evaluating the proposed solutions' effectiveness and feasibility for a characteristic town. The results of the consultation data analysis and SWOT analysis provided insight to solutions which met the stakeholder needs of the IoT town. The completion of the methodology enabled the team to propose a recommended smart parking system that incorporates various technologies to address shortcomings of current smart parking systems in Hangzhou, China.

Chapter 4: Results and Analysis of Collected Data

This chapter analyzes and organizes data obtained during the team's observation, survey, and interview periods of the project's development. In order to satisfy the goals set in Objective One, the team analyzes the data through coding tables and conclusions drawn from observations and stakeholder consultations. By finding parallels between the three separate data collection methods, the team discerned consumer and provider needs for smart parking systems. The consumer and provider needs reached in this chapter allowed the team to properly approach further research necessary to evaluate potential smart parking solutions for the Internet of Things (IoT) town in Hangzhou, China. The consumer and provider needs addressed at the end of this chapter are the foundation for the team's proposed recommendations to the project sponsor.

4.1 Results and Analysis of Natural Observation Period

This section summarizes the team's relevant findings derived from the observations of six different parking complexes in Hangzhou as seen in Figure 12. The team performed observations and recorded key characteristics in the observation table seen in Appendix I. This section summarizes in detail the findings from the six parking complex observational events noted in the observation table. The final summary organizes and analyzes major themes revealed across the individual parking complex observation summaries.

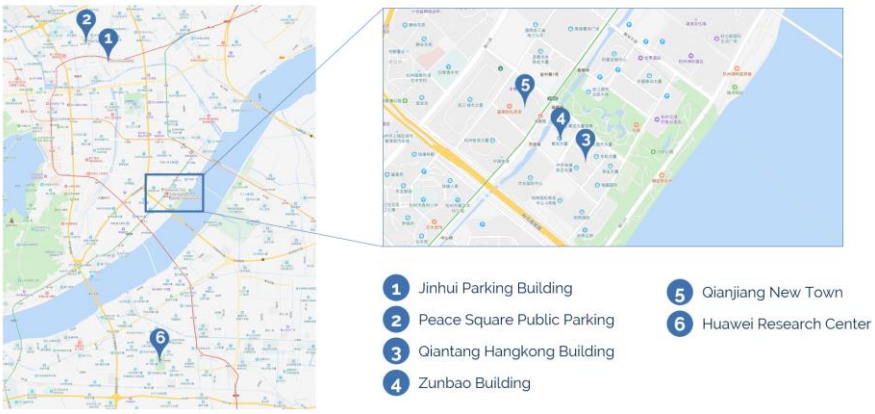

Figure 12: Map displaying the parking complex observation locations

4.1.1 Summary of Jinhui Parking Complex Observation

The Jinhui complex, the first observational site of this investigation, is a six-floor above ground facility with a smart parking system in a suburban area of Hangzhou. The project team noticed that there was zero notable large businesses or attractions nearby the facility, and thus the team suggested that the parking facility offered parking for various surrounding small businesses and residential buildings. The complex had sufficient fire prevention and suppression systems, as well as natural and fluorescent lighting. There was a security guard placed at the access level of the facility, with private security observation offices on each floor of the complex. At the base of the complex was a car detailing, wash, and repair shop that was attracting many customers (see Figure 13). Lastly, there were many electric car charging stations installed on the ground floor to attract customers into the facility as well. The team recorded many customers during the day entering the complex solely for the car shop or electric charging stations, rather than to park at all.

Figure 13: Jinhui car detailing and repair shop

The complex's smart parking system primarily used OCR cameras at the entrance and exit gates, as well as within the facility. The OCR cameras at the entry and exit level captured license plate photos to store in a database. A car that entered the facility viewed digital signs displaying the number of available parking spaces on each floor. The system obtained this information through OCR cameras placed over each parking space. If the system identified a

vehicle in a parking space, the system would mark the spot as occupied and a green LED over each parking space would turn red (Figure 14 demonstrates an example of these LED lights). This LED light marks the parking spot as occupied, and the digital signs in the facility updated in real-time to reflect the total number of available parking spaces. The combination of LED lights over each parking space and the digital signs made the process of finding available parking much easier for consumers than traditional parking complexes. In a few instances the LED indicators were inconsistent, as they would incorrectly flash between green and red. While the system did make the process of finding available parking spaces convenient, it did not offer the function of displaying where an owner parked their vehicle.

Figure 14: Jinhui OCR camera marking a vacant spot

4.1.2 Summary of Peace Square Parking Complex Observation

The Peace Square Parking Building is a seven floor, above ground parking complex which utilized simple OCR and RFID technology to manage the parking complex. The front gate of the complex used RFID technology to accept customers' passive RFID cards. The complex had OCR cameras placed periodically throughout the complex rows, and LED lights placed above every parking spot. The interior of the complex was rather simple, with minimal applied technology and navigation solutions. On the first floor of the complex, there was a large security room with numerous personnel. Natural and fluorescent lighting lit the entire complex, along

with visible exit signs over the location of stairs and elevators. In comparison to the other parking complexes, the team noticed that Peace Square complex lacked in physical upkeep and cleanliness.

The navigation and vehicle management system of the Peace Square complex was inconsistent. There was a simple counter located on each floor that displayed the available parking space total for that floor, but none of the counters were in operation. The team hypothesized that this could potentially be due to the OCR cameras intermittently, incorrectly marking parking spots. Figure 15 demonstrates the malfunctioning of the OCR camera's detection. The figure displays a vehicle parked in a parking space with an LED light displaying that the parking space is vacant. As in other OCR-based complexes, green LED lights indicated open spots, which the system turned red when occupied. Considering the OCR system was not working consistently, the team realized that this behavior made finding an open spot harder for complex customers. On the top floor of the complex, there was a rather dilapidated area reserved for roof parking and charging electric vehicles. All of the charging stations lacked power and appeared unused for a long period of time.

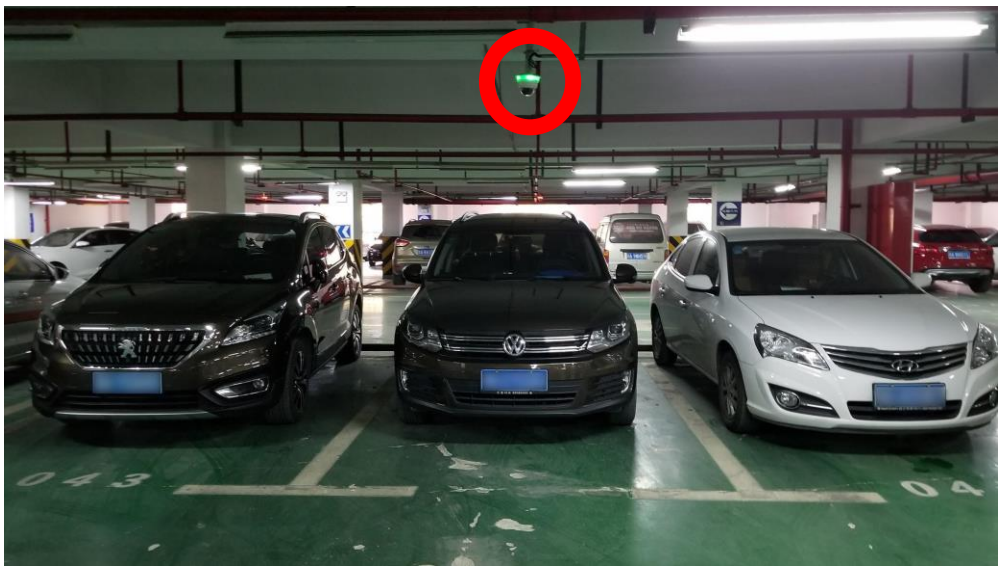

Figure 15: Malfunctioning OCR camera, Peace Square Parking Lot

Regardless of the rather un-impressive infrastructure and facilities of the complex, there was a constant flow of vehicles arriving and leaving this parking complex. Parking complexes placed in major cities typically have primary factors that qualify their location. In the case of Peace Square Public Parking, the parking complex served as the primary parking solution for a

major mall. Additionally, the project team observed reserved employee parking spots for nearby businesses. The public parking customers paid a personnel member positioned at the exit gate using Alipay. The parking rate of the garage was four yuan per hour (up to 24 hours), and free for customers with reserved business spots.

4.1.3 Summary of Qianjiang New Town Time Square Parking Complex Observation

The Qianjiang New Town Time Square parking complex serves a group of hotel and apartment buildings near the Citizen Center in Hangzhou. The parking complex itself was strictly underground and therefore primarily lit by artificial light. The size of the complex was arguably the largest that the team visited. Additionally, there were areas throughout the complex which posed a safety concern for customers and personnel as they did not provide sufficient lighting. The lot's floors had distinct sections labeled by letters (lot A, B, C, etc.) to help users navigate within the complex, which were all painted with a distinguishing color, as shown in Figure 16. All three underground levels displayed the identical layout and corresponding color scheme. Each floor had easy access to both elevators and stairs, which incorporated flood doors to protect from natural disasters or biotech attacks. The lot had very few CCTV cameras and instead had many security personnel stationed near the exit ramps of the complex. While there was no "smart" technology to verify spot occupancy, there were electronic alarm gates at certain spots which required security assistance to unlock. Each floor had specific areas reserved for electric vehicles and their charging stations. The team identified the complex as very safe due to the security personnel presence. The demographics of vehicles led the team to believe that customers of this lot were of the upper-class, and probably paid a higher premium for their parking spot in return for being located in a high-quality complex.

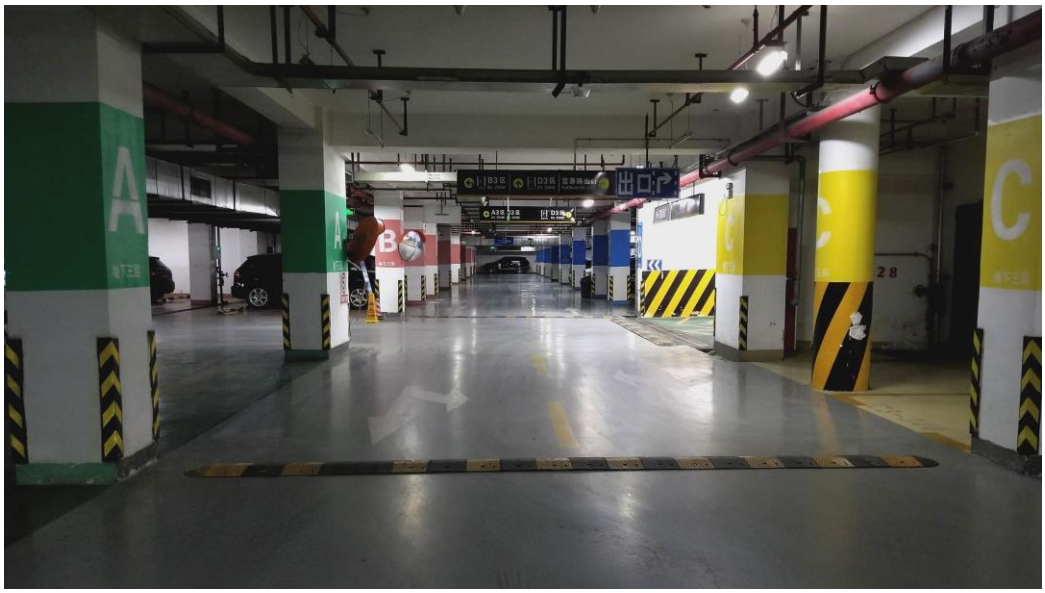

Figure 16: Parking complex floor divided into sections by colors and letters, Qianjiang New Town

The Qianjiang New Town Time Square parking complex did not incorporate many sensing technologies in their parking management and strictly used analog navigation techniques. The only smart parking system in place was an OCR camera located at the front gate which recognized permanent resident vehicle spaces. The team believes customers pay for the public parking spaces with printed receipts and mobile payment methods at the front gate. Throughout the complex, there were QR codes for non-permanent customers to prepay for parking using WeChat Wallet or Alipay. Aside from the front gate's OCR cameras, there were no vehicle identification and management systems within the facility.

4.1.4 Summary of Qiantang Hangkong Parking Complex Observation

The Qiantang Hangkong Building is a three-floor underground parking complex located in the downtown area of Hangzhou. The student from Hangzhou Dianzi University informed the project team that the area is well-known for its modernized buildings and skyscrapers. The team spotted a concentration of hotels, corporations, shopping centers and tourist attractions around this area. Further observations identified no particular demographic pattern due to a variety of vehicle types, however, a large number of vehicles were expensive as stated in other parking complexes. Many poorly lit areas and a lack of sufficient security cameras posed a safety concern when taking into consideration the massive size of the parking complex. Lastly, the

directions to the exit had severely faded paint, providing no clear guidance for a vehicle around the complex.

The parking complex did not incorporate many sensing technologies and information systems in the parking complex. The only system in place at this complex was the OCR cameras found at the entrance and exit gates. One notable detail about the gates at the Qiantang Hangkong complex is that they use two gates when processing vehicles to deter vehicles from "tailgating" behind the car in front of them. The OCR cameras in front of each gate captured the vehicles' license plates to authorize them to enter the complex. Furthermore, the parking complex used two parking spaces reservations techniques. The first reservation technique consisted of a physical lock that a guard or customer with the key would manually unlock. The second reservation technique consisted of a black plate that contained the vehicles plate number. This second reservation technique appeared problematic as there was no physical restriction that denied any other vehicles from accessing the parking spot.

Additionally, the parking complex did not offer a navigation system to find a vacant parking spot, or an interface to direct users to their parked vehicles. This makes it difficult and time-consuming for customers to find an available parking spot during peak hours. The tollbooth at the entrance of the facility processed customer payments with WeChat Wallet, Alipay or cash. Overall this parking complex appeared to be a more traditional parking complex located in a modern area of the city of Hangzhou.

4.1.5 Summary of Zunbao Building Parking Complex Observation

The Zunbao Building parking complex is a private parking lot with three floors below ground. The same parking management company as the Qiantang Hangkong Building operates the parking complex. The parking lot charges a parking fee of 6 yuan per hour (up to 6 hours). The project team's observations indicated that users use Alipay for the majority of parking fee transactions. Instead of RFID technology, the complex used OCR cameras to identify registered and unregistered vehicles. There was a large number of security present across the parking complex, with security guards at the entrance and many scattered across each floor of the complex. Technology is less prevalent in the complex, as signs displaying the license plate number of eligible vehicles mark the parking spaces. Some parking spaces had physical locks that required security personnel to manually unlock them for specific vehicle owners. The

parking lot also had a poor guidance system, with no display of parking spot availability and very few navigation signs present on the floor. The vehicle demographic appeared to vary, however, the parking complex was very busy with employees dressed in full-suit attire. Many of the customers expressed that they were too busy to participate in the project team's survey. The project team believes that the parking lot has several safety concerns, as there was a lack of CCTV cameras and fire suppression systems across the parking lot.

4.1.6 Summary of Huawei Parking Complex Observation

The project sponsor facilitated a site visit to Huawei, a characteristic town very similar to the Internet of Things town. This project used Huawei as a representation of the IoT town, as both are similar in physical construction and employee needs. This location represented the characteristic town to the project team, as they were unable to enter the target characteristic town due to high-security reasons. Huawei's characteristic town has underground parking complexes strictly for employees and approved visitors. The parking complex at Huawei had three underground levels for employee and visitor parking. The parking complex was not open to natural light, however, it did offer sufficient fluorescent lighting. The top floor had one security person positioned on the top floor at a desk adjacent to the elevators. There were sufficient fire suppression and prevention systems, and the parking complex was very clean.

The parking system at Huawei was notably the most efficient, yet far simpler than other solutions applied in the six observed parking complexes. Acting as a screening process, the parking complex's entrance is the main gate of the companies. At the gate, an OCR camera screened entering vehicles. If the captured license plate of the vehicle matched a registered employee's license plate, the system granted access to the vehicle. If the license plate was unregistered, the security personnel prompts the driver for the necessary credentials. There were digital signs positioned around the complex that displayed the available parking accurately within the parking complex, as seen in Figure 17.

Figure 17: Huawei parking complex entrance with digital display for available parking spaces

Figure 18 displays the LED lights and ultrasonic proximity sensors positioned at each parking space. The ultrasonic devices detected when a parked vehicle was beneath it after approximately fifteen seconds by analyzing the difference between the device's transmitted sound waves. LED lights displayed the parking space as vacant or occupied to customers, according to the proximity sensor's identification. During approximately thirty minutes of observation, the project team witnessed no errors in parking spaces such as incorrectly marking spaces as vacant or occupied. It was unclear whether the vehicle owners were able to locate their already parked vehicle through a navigation interface such as a mobile application. However, there was no evidence of physical terminals in the parking complex.

Figure 18: LED lights and ultrasonic proximity sensors observed at Huawei

4.1.7 Summary of Observation Period Findings

The project team's parking complex observations proved to be a crucial aspect of the project, as the parking complexes were vastly different than parking complexes the team was accustomed to in the United States. Because of the differences, the observations revealed many useful characteristics and trends of Hangzhou's parking complexes. The observation sites consisted of a variety of different complexes that each had a unique purpose. Observation sites such as Jinhui and the Peace Square Parking were parking complexes that used smart systems in an attempt to increase parking efficiency and convenience for the surrounding areas. Other observation sites, such as Qianjiang and Qiantang, used technology solely at the entrance and exit toll booths and more traditional parking methods across the rest of the parking facility. It is important to state that all of the sites excluding the Peace Parking Square provided only underground parking. The project team assumed parking complexes to be located underground in order to efficiently utilize the limited land area of Hangzhou.

A major parking complex characteristic witnessed across all of the observation sites was the implementation of mobile payment options. All of the parking solutions accepted Alipay, or WeChat Wallet, yet more often than not both mobile payment applications. The team marked two main methods of accepting these non-contact payments. The most prevalent was the use of QR codes located along the walls of each parking complex, as seen in Figure 19. While this was easily accessible and did not require additional management personnel, it often required the customers to walk a distance from their vehicle to complete their payment. The second, more manual payment method was the use of Alipay and Wechat Wallet at gated tolls located at the exits of the parking complexes. Here, hired personnel would accept payment from the customers leaving the parking lot. Regardless of the payment process, both methods required that the customer spends additional time within the parking complex.

Figure 19: QR code poster for payment of Qianjiang New Town Time Square Parking Complex

Another key observation involved the overall technology witnessed across parking complexes in Hangzhou. Upon traveling in Hangzhou prior to project observations, the team noticed OCR cameras positioned at nearly every parking entrance toll booth across the city. The prevalence of OCR cameras repeated when the team went to the observation sites discussed throughout section 4.1. OCR cameras were the main form of vehicle identification used across parking complexes in Hangzhou, regardless of the parking system used within the complex. The project sponsor indicated that the Chinese government widely accepted OCR technology and thus invested in its further development. Due to the government's focus on OCR technology, many corporations and research centers further developed the technology which lowered the overall cost. The main differences in technology were within the parking complexes themselves. The Qianjiang New Town Time Square, Qiantang Hangkong, and the Zunbao Building parking complexes all lacked smart technology within the parking complexes. These complexes used OCR cameras at the access level of the facility. However, within the facility, they used traditional parking spaces with reserved parking spaces indicated by a sign displaying specific license plate numbers.

In smart parking complexes such as Jinhui and the Peace Parking Square, each parking space had OCR cameras above each parking space with a corresponding LED light. The OCR camera detected if a vehicle was within a specific parking space which then displayed the result

in a LED light. While this system was helpful for customers, the system malfunctioned frequently as it incorrectly indicated many parking spaces as vacant. On the other hand, Huawei used ultrasonic sensors above each space which produced very few errors. The ultrasonic sensors were simple, as they recorded differences in the time it took for transmitted waves to register as reflected. However, Huawei's smart system worked effectively and therefore displayed a need for less management personnel.

Aside from the overall car demographic and general system technologies that parking complexes were using, the team discerned the presence of management personnel and general user and vehicle safety. Amongst the Jinhui and Peace Parking Square parking complexes, there were observation rooms with two to three security personnel monitoring the facilities. In addition, one security personnel remained at the entrance and exit toll booths. The other parking complexes, excluding Huawei, had security personnel monitoring the complex from an observation room, along with guards stationed at high traffic areas. The areas that had no technology had chairs around the parking facility for security guards to watch and open physical reservation locks for customers. Huawei's efficient smart parking system allowed the entire complex, consisting of over three floors, to have only one management person located at a desk on the top floor. This observation supported the team's assumption that a smart and efficient parking system could largely reduce the management personnel of the characteristic town and thereby the overall maintenance cost. The authorization of only verified visitors and employees could influence the reduction of management personnel at Huawei. However, this condition was also the case at some of the other parking complexes. General user and vehicle safety observations consisted of lighting, fire suppression systems, and sufficient emergency exit signs. All of the observation sites had sufficient fire suppression systems and exit signs. However, the team realized that sufficient lighting was lacking in many of the facilities. This poses a large security concern at night for both users and vehicles.

4.2 Results and Analysis of Surveys

In order to gauge the overall customer satisfaction with the observed parking complex locations, the team conducted seventeen brief public surveys at four different parking locations (seen in Figure 20). As previously discussed in Chapter 2, the success of smart parking solutions

heavily relies on positive customer experiences. The multiple choice and short answer questions probed for customer opinions on the technology and design of each parking complex. The team anticipated that not every survey question would offer a noticeable trend, as often survey subjects were in a rush or may have misinterpreted the purpose of certain questions.

There were three specific trends noticed in the responses at all four survey locations. Section 4.2.1 outlines the general demographic of customers interviewed, taking into account their vehicle and reason for parking. Section 4.2.2 analyzes the first noticed customer opinion trends in survey results on the applied technology and parking complex inconveniences. The analysis in section 4.2.3 highlights the effectiveness of current vacancy identification methods using customer responses at the four parking complexes. The final summary in section 4.2.4 organizes the present trends and considers their importance in reaching conclusions on customer needs.

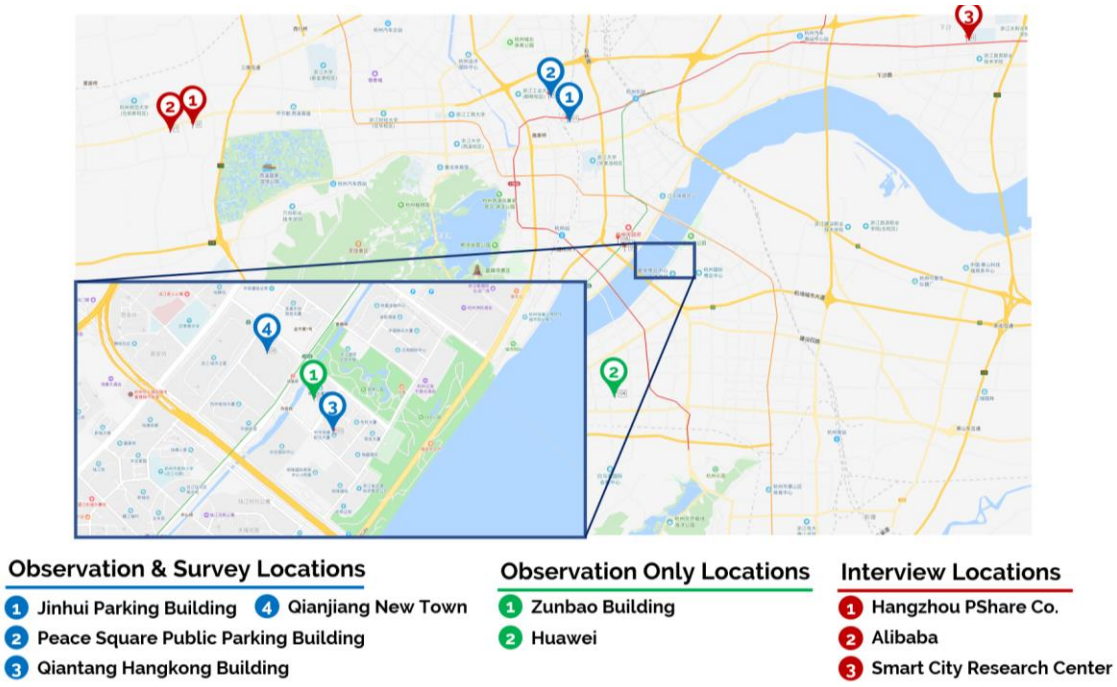

Figure 20: Map displaying survey, observation and interview locations in Hangzhou

4.2.1 Survey Demographic Findings

Knowing the general demographic of the survey subjects influences the relevance of the subjects' opinions on parking complexes in Hangzhou. The first three questions in the customer and user surveys enabled the team to gather demographic information regarding the seventeen

surveyed individuals in the various parking complexes. As seen in Table 3, the cells highlighted in purple group data regarding the vehicle type, the parking space type and the reason for parking in the complex. The answers to the first question (displayed in the row "What Vehicle?") indicate that nearly all (88%) survey subjects drove a regular vehicle. The second question in this section revealed the wide variety of parking spaces that the subjects used to park their vehicles. This demonstrated that vehicle owners park their vehicle where parking spaces are available, and not in just one type of routine location.

Survey Responses - Demographic Questions																
Abbreviations:	**JHP** = Jinhui Parking Building, **PPP** = Peace Square Public Parking Building, **QHB** = Qiantang Hangkong Building, **QTT** = Qianjiang New Town Time Square, **RC** = Regular Car, **EC** = Electric Car, **M** = Moped, **P** = Private , **S** = Street, **C** = Commercial, **SH** = Shared															
Subjects	**Subject 1**	**Subject 2**	**Subject 3**	**Subject 4**	**Subject 5**	**Subject 6**	**Subject 7**	**Subject 8**	**Subject 9**	**Subject 10**	**Subject 11**	**Subject 12**	**Subject 13**	**Subject 14**	**Subject 15**	**Subject 16**	**Subject 17**
Parking Lot	**JHP**	**JHP**	**JHP**	**PPP**	**PPP**	**PPP**	**PPP**	**PPP**	**PPP**	**PPP**	**QHB**	**QHB**	**QHB**	**QHB**	**QTT**	**QTT**	**QTT**
What Vehicle?	RC	RC	EC	RC	RC	RC	RC	RC	RC	RC	RC	RC	RC	RC	RC	M	RC
Usual Parking Spot	P	S	S	C	C	C	C	C	C	C	P	SH	SH	S	SH	C	P & S
Why Parking in this Parking Lot?	Official Business	Official Business	Charging Only	Business	Business	Company is Nearby (Convienence)	Convenient	Business	Business	Easy access to the (subject's) company (Convienence)	Convenient	Convenient	Work nearby, convenient	Work nearby, convenient, surroundin g area have less parking lot	Convenient, need to resolve something here so parked here.	Convenient, has security people taking care of it.	Other parking lot have no available spaces.

Table 3: Customer and user survey responses - demographic questions (num = 17)

The recent high influx of vehicle ownership in Hangzhou has led users of these parking complexes to have no overall preference on the type of parking space. Instead, the survey result indicates a need for improved availability of parking spaces. The third question representing the customers' demographic enabled the team to ascertain the parking purpose of the individuals. The surveys indicated that the majority of survey subjects were employees of companies near the parking complex. This in conjunction with the observed vehicle characteristics in section 4.1 signifies the overall demographic of the interview subjects to be middle to upper-class employees that mainly use these parking complexes because of the availability and convenience. Moreover, this survey result directly correlates with the team's observations of consumer demographics at Hangzhou's parking complexes.

4.2.2 Parking Availability and Applied Technology Findings

As shown in the Table 4, the cells bordered in blue demonstrate the relationship between people's response to the question "Do you think the technology provided is sufficient?" and their

response to the inconveniences of the parking lot. The highlighted cells identify two trends within the responses.

Survey Responses - Technology Questions																	
Abbreviations:	JHP = Jinhui Parking Building, PPP = Peace Square Public Parking Building, QHB = Qiantang Hangkong Building, QTT = Qianjiang New Town Time Square																
Subjects	**Subject 1**	**Subject 2**	**Subject 3**	**Subject 4**	**Subject 5**	**Subject 6**	**Subject 7**	**Subject 8**	**Subject 9**	**Subject 10**	**Subject 11**	**Subject 12**	**Subject 13**	**Subject 14**	**Subject 15**	**Subject 16**	**Subject 17**
Parking Lot	JHP	JHP	JHP	PPP	PPP	PPP	PPP	PPP	PPP	PPP	QHB	QHB	QHB	QHB	QTT	QTT	QTT
Technology Sufficient?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes	No	Yes	Yes	No
Any Inconveniences?	N/A	N/A	N/A	N/A	Too many entrances/exits makes the parking complex confusing.	N/A	N/A	Pedestrian share space with cars which makes it very dangerous. Also, there is no way to tell floor availability.	N/A	Hard to find parking spots when going to a parking lot for the first time.	Private parking spot sometimes got used by other people.	Hard to find parking spots and expense is high.	Temporary parking cars park in private spots. Parking complex get's clogged when leaving from work.	Cannot find his own car and parking fee payment method is not convenient.	Passage can be jammed in peak hours, not many parking space available, parking fee is high and hard to find car.	N/A	Hard to find parking spaces and own car.

Table 4: Customer and user survey responses - technology questions (num = 17)

The survey results indicate that Hangzhou citizens are usually more accepting of new technologies if they demonstrate increased efficiency. In the cells colored in green, the survey respondents believed that the technology is sufficient in the parking lot, and they did not indicate any inconveniences in the parking lot. On the other hand, the cells colored in cyan highlight responses where people are less acceptable with the technologies that were working poorly. A common trend is the subjects desiring a display that shows parking lot and floor availability. Many of them experienced certain difficulties in finding available parking spots and stated that the technology provided by the parking complex was inadequate. Hangzhou is a city with a massive number of vehicle owners, and thus parking spaces are extremely limited. Without a proper technique to indicate available parking spots, customers may need to drive aimlessly around in a parking complex in order to find an empty parking spot, which may sometimes yield no successful result. A system that displays available parking spots shortens the process of finding an empty parking spot and prevents vehicle owners from aimlessly driving in a parking lot that is already full.

4.2.3 Vacancy Identification Findings

The project team conducted surveys at four public parking complexes, which differed greatly in applied technology. Two of the four survey sites had LED lights on top of the parking lots to indicate vacant parking spots, while the other two had no vacancy indicator. An OCR camera recognized vehicle license plates and a corresponding LED light on the camera turned

green if the camera recognized a license plate. During the observation period, the team noticed that the OCR cameras sometimes malfunctioned, leading to incorrect displays of parking space availability.

The project team spotted a trend in customer difficulty when searching for available parking space as depicted by the bar graph in the Figure 21. Only 7 respondents believed that finding an empty spot inside a parking lot was easy, regardless of whether the parking lot had a parking space vacancy indicator or not. Many respondents mentioned that the parking lot usually does not have sufficient parking spots to meet the demand. The survey responses strengthen the need of having a clear and effective vacancy indication system. As for the current LED indicators, based on observation results, the project team believes that they are sufficient for guiding customers to empty parking spots. The LED lights properly express a parking space vacancy, however their accuracy is dependent upon the vehicle sensing technology. For example, the Peace Square Public Parking complex's OCR cameras malfunctioned which caused incorrect identifying of parking spaces as occupied or vacant. Therefore, the results from the customer surveys at the complex displayed some customer dissatisfaction with the technology in the parking complex. However, in Huawei the vacancy identification was very accurate and the LED lights properly displayed the location of available parking spaces. Therefore, this suggests that LED light indicators are effective in displaying available parking spaces, however the vacancy identification technology must be accurate and efficient in order to obtain customer satisfaction.

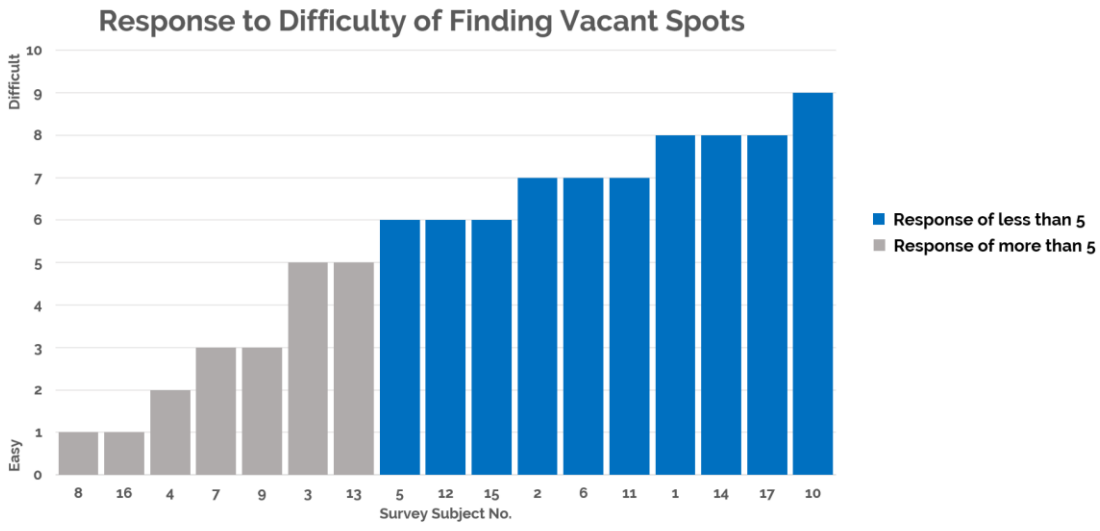

Figure 21: Survey subject's individual responses to vacancy (num = 17)

4.2.4 Summary of Findings from Parking Complex Public Surveys

The surveys yielded insight into the shortcomings of the current smart parking systems from the current customer's perspective. While the team quickly recognized that many customers were not open to participating, the subjects who did answer questions offered a wide array of opinions on how current systems are falling short of reaching higher efficiency levels. The results show that the demographics of subjects surveyed were relevant to the potential users of their final recommendations. When compiling the collected data, the team found that nearly 60% of the surveyed customers had chosen the parking lot for business purposes. When considering recommendations for the IoT town, the team understood that similarly, most if not all of the customers would use the IoT parking complex for business purposes.

The results from the 17 administered surveys focus on the overall customer experience in relation to the applied technology. The trends between survey results primarily fall within the theme of availability and convenience of the parking complex. The correlation between whether a customer felt the technology was sufficient, and whether they encountered any inconveniences allowed the team to see two separate customer experiences. Customers who stated the technology was sufficient typically recorded that there were no notable inconveniences. This result implies that for these customers, the applied technology in the parking complex had been functioning properly which ultimately led to customer satisfaction. All customers who believed that the technology was sufficient, yet still recorded an inconvenience, discussed issues they saw with the physical infrastructure of the parking complex.

Responses that indicated the current technology as inconvenient also recognized shortcomings regarding the availability and vacancy identification methods used in each of the surveying locations. The distinct difference between responses makes it clear that while the applied technology does work, it is neither consistent nor leaves the entirety of the parking customers satisfied. The processed survey results reveal that these consumers place high importance on finding an available parking spot efficiently.

The fact that only 35% of the subjects rated finding an empty parking spot as easy (5 or below) reinforces this revelation. While two out of the four survey locations used LED vacancy indicators, there was nearly an even number of subjects claiming it was difficult to find an empty parking space. The difficulty arose from the vacancy identification techniques that the system used, because incorrectly marked parking spaces confused customers and resulted in them

driving around aimlessly. This led the team to the belief that the current methods such as LED lights are effective for displaying a vacant parking spot, however the technology that identifies a parking space as vacant or occupied must be accurate. Furthermore, the results imply that the vacancy identification technologies require further development in the team's proposed solution for the IoT town.

4.3 Results and Analysis of Interviews

This section details the team's results derived from formal interviews with industry experts and graduate students who are relevant to the development of smart parking. Figure 22 shows the three interview locations. This section contains four subsections that encompass the three stakeholder groups and a general findings summary. Each subsection discusses the subjects interviewed and their relevance to the overall project research, in addition to the notable qualitative data expressed during the interview process. The final summary organizes and analyzes the data summarized in the earlier subsections, and references a coding table created during the assessment of the interview transcriptions.

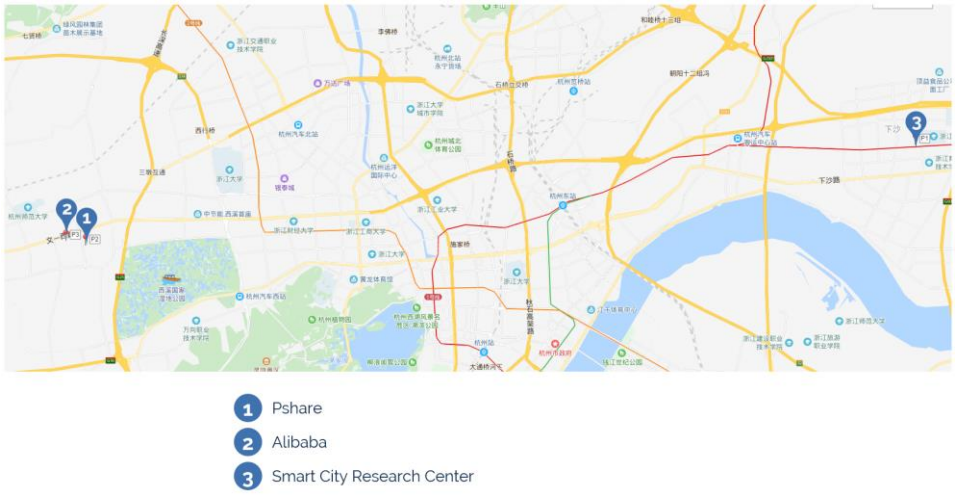

Figure 22: Map displaying interview locations

Hangzhou PShare Company

The team performed four interviews while visiting PShare during a sponsor facilitated site visit. PShare has been developing modern IoT based parking locks since 2014 as a company working under Alibaba as a verified distributor. The company primarily focuses on the

integration of Bluetooth and RF technologies into smart parking locks (Figure 23). This small company has multiple patents pertaining to smart parking and the technologies they are currently developing.

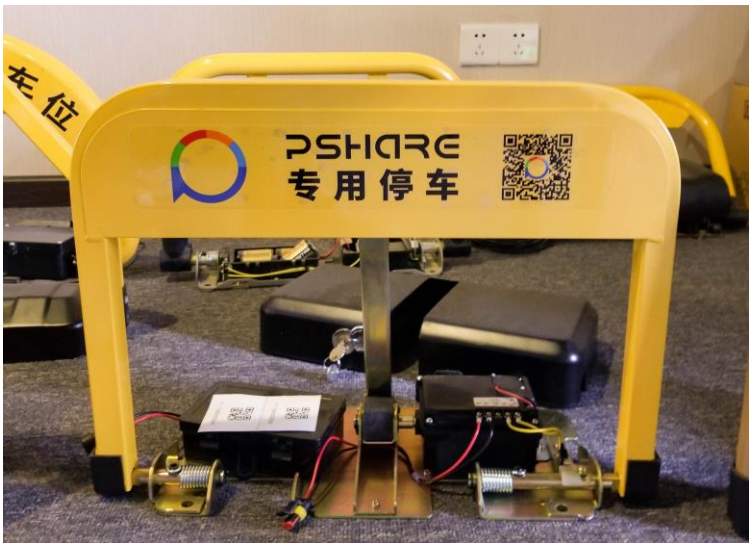

Figure 23: Picture of smart parking lock at Hangzhou's PShare Co. Headquarters

4.3.1 Expert Interview with Backend Software Engineer of Hangzhou PShare Co.

The first subject interviewed while at PShare Company in Hangzhou, China was Jie Lu, a backend software engineer who focuses on server-side software. He explained that PShare does not actually create software solutions for smart parking, but he focuses on the integration of their parking solutions as a network endpoint (socket). While Jie Lu primarily contributes to the development of software, his role in the small company exposes him to the various aspects of hardware design e and smart parking as a whole. Jie mentioned that PShare had already developed a successful parking solution with applications applied across the globe. Jie stated that Tesla had partnered with PShare to deploy parking locks across Tesla charging stations in many countries. The partnership between the two companies allowed Tesla vehicle owners to search for a nearby charging station on their mobile device and reserve the space via a mobile application. Jie discussed further that his company was interested primarily in the development of future solutions. The interviewee mentioned that the project team's solution would be a future solution for the IoT characteristic town, which was a relatable goal between both interview parties.

When having an open discussion about the current state of smart parking, Jie said that he felt that the current closed complex parking solutions that the project team observed were well developed. Despite the potential error in OCR camera solutions, Jie felt that the solutions were adequate for both public and private closed complex solutions. Consequently, PShare was putting significant efforts into creatinging solutions that targeted open parking lots. He mentioned that he felt parking IoT connected locks would be a future trend, yet parking lots would need labor forces to support the locks until implementation of parking locks became common.

Understanding the idea that different parking lots required diverse supporting technologies, Jie offered LORA, RS485, and Narrow Band Internet of Things (NB-IoT) as technologies that had a potential for future smart parking solutions. He felt there was no "all around" technology that could solve all problems of smart parking. Instead, each technology has its own strengths and weaknesses that could complement one another. When discussing LORA and RS485, Jie drew attention to the choices in Internet connections in many smart parking solutions; as LORA is wireless and RS485 requires wires. The project team considered the method these technologies use to transmit data when developing the final solution, as the need for physical wiring or wireless transmissions plays a significant role in overall system logistics.

The team discussed the importance of smart parking characteristics with Jie, who believes that safety should be a major concern of the team. He described safety as a need for a solution which allows customers to park their vehicle with peace of mind that the parking complex would be secure, and only open to other customers. When further discussing potential smart parking solutions, the team offered Jie a question regarding what data would be beneficial to record during the operation of a smart parking solution. He felt that recording data on customers' time of parking and their desired price could allow for a future solution which offers recommendations of similar parking complexes. During the conclusion of the formal interview questions, the team asked Jie if he had any suggestions for the team to aid in the development of a smart parking solution. While Jie did not feel as though he was qualified to offer technological recommendations, he clarified that there were qualities of modern smart parking systems which he felt may prove effective in the IoT town. He suggested that combining the technologies of parking space locks and toll booths would allow for a secure system, and the implementation of OCR would allow for the proper identification of customer vehicles.

4.3.2 Expert Interview with Hardware Engineer of Hangzhou PShare Co.

The second interview subject during the sponsor facilitated visit to PShare Company was a hardware engineer named Zhanyi Shi. He stated that his job consisted of the design work for the physical locks and printed circuit boards (PCBs) which PShare creates. Like Jie, Zhanyi stated that PShare had created a successful and effective parking solution, and they are working on future developments to improve upon the issues which their original solution does not solve. The team discussed these future solutions with him further. Zhanyi believes that digital vehicle tags with applied wireless communication will be the future. He told the project team that government involvement will eventually lead to the requirement of a uniform city-wide smart parking solution for city-wide implementation. He claimed these tags may end up being RFID based, but he emphasized that 5G cellular connections had the most potential as 5G is easily adaptable in systems that used prior cellular connection technologies. The ability to utilize hardware from prior systems doubles its value, as cellular connection technology is already low cost, and most customers already have capable smartphones with them while parking.

Zhanyi indicated that system efficiency was the most important factor of a successful smart parking solution. He mentioned that taking into account the number of available parking spots, along with the ratio of current vehicles available spots are data points which can improve the operation of a smart parking system. During an open discussion around his response, the interviewee suggested that showing complex availability can improve overall system efficiency through attracting customers when there is vacancy and turning customers away when full. To conclude the interview, the project team asked Zhanyi if he had any specific suggestions for the team's solution. He stated with the recent adoption of IoT technologies in many fields, he felt that 5G would be most applicable in future technologies. He explained 5G's strengths in that it transmits data efficiently and has a long range. With this in mind, Zhanyi added that there are many potential applications of current technology that could create a modern and effective system. He described a system with OCR cameras, parking locks, and displays in a parking garage, stating that a combination of technologies is currently the most effective method of creating a sufficient smart parking system.

4.3.3 Expert Interview with Hardware QA Engineer of Hangzhou PShare Co.

The third interview conducted by the team was with Weijie Li, one of PShare's QA Engineers, a valuable interview subject as the role typically deals with the improvement of current solutions. Weijie stated that his position requires him to interact with customers to provide and improve PShare's smart parking solutions. He reiterated that the company's main goal over the past few years dealt with developing a market for automatic and remote controlled parking locks. During the discussions, the team asked Weijie where he saw the market heading in the future as smart parking solutions develop. He offered a completely new viewpoint, as he believed that shared parking would become more common with the increased use of shared vehicles, cars with no specific owner which are available to rent. He claimed that PShare was aware of this market trend and they were in the process of developing new solutions. Weijie said there is a potential for smart parking to transition from parking spot management, into shared vehicle smart locks.

When asked about the most important factor in a smart parking solution, Weijie disclosed that vehicle safety is by far the most important characteristic. He followed this by stating that parking complexes need information on the number of present vehicles to offer available parking spaces to local residents. This need for vehicle safety comes into play heavily when considering offering shared parking at a smart parking complex. Weijie's comments on shared parking and smart parking solutions suggested to the project team that a major consideration of smart parking solutions is the effectiveness of its safety. When discussing recommendations for the team's solution for the IoT town, he believe that big data is important for creating an efficient system. He furthered this by describing potential techniques to detect and track vehicles throughout the parking complex. Weijie mentioned various technologies which the team had previously witnessed in parking complexes throughout Hangzhou, such as ultrasonic sensors as a form of vacancy identification. One key point was Weijie's comment that cameras (such as OCR) may become obsolete in the near future. Weijie clarified this idea by explaining more effective wireless transmission sensing systems applied to current smart parking such as RFID and 5G.

4.3.4 Expert Interview with CEO of Hangzhou PShare Co.

The last interview subject at Hangzhou PShare Company was the CEO, Hongcheng Shen. The team was fortunate to spend significant time with Shen while at PShare and asked numerous

questions throughout the day. When conducting the interview, the team first asked the company founder to discuss his company's goals for developing smart parking in Hangzhou. Like the other interview subjects, Shen offered that his company has been providing intelligent smart parking solutions for Hangzhou since 2014. Shen indicated that PShare had strong backing on their current technologies, and his company focused on creating parking solutions for the future. He later eluded to these solutions as meeting all customer requirements through the incorporation of multiple technologies. Shen mentioned three solutions his team had specifically applied to smart parking, Bluetooth, LORA, and Zigbee communication. When discussing the development of any type of smart parking solution, Shen felt that availability is the most important factor for both consumers and providers of smart parking. He explained that knowing the parking spot availability creates a more efficient system for consumers considering using the parking complex. With this information, the team shifted discussion towards the solution we were developing. When asked if he had any recommendation Shen offered his opinion that an effective parking solution solves two distinct problems. The first problem is that space is very limited and a solution needs to maximize the utilization of the available space. Furthermore, he expressed that smart parking solutions must be applicable to not only the current physical parking infrastructure, but also the distinct country, region, or building. Before concluding the formal interview, Shen began discussing future possibilities in shared parking complexes for everyday citizens to use at night.

4.3.5 Expert Interview with an Employee of Alibaba

The fifth interview conducted by the team was with two of Alibaba's marketing employee's, a valuable interview since their roles typically deal with new product development and customer interactions with Alibaba's technologies. According to the interviewees, Shuai Li and Li Yuan, Alibaba focuses on payment methods and cloud computing. With the wide use of Alipay (seen in Figure 24) in Hangzhou, the team asked the interviewees what other future payment technologies they were researching. Shuai stated that in the future reducing the costs of non-contact payment method with new technologies would benefit customers and management personnel. He gave the example of cutting smartphone payment usage and using biometric signatures to perform everyday transactions and direct payments. This biometric data could include facial recognition, fingerprint identification or vocal print payment that would enable

customers to pay without the use of a device, thus making it faster and more convenient. He noted that Alibaba was aiming for the customer's convenience and the automation of the whole payment processes.

Figure 24: Alipay app home screen screenshot (Chinese version)

When asked if consumers would prefer a specific payment method, Shuai believed that it was highly dependent on the situation. He followed this with the idea that that big transactions would need robust procedures, whereas small daily transactions should be fast to improve the user experience. Further in the discussion, the team asked if future technology, like the device-less transactions, would pose any social concerns. Shuai stated that since the technology was still in the development stage he could not make any remarks about it. But later in the interview when the team asked if there was any information a parking lot should not be collecting the interviewees opined that the Chinese public was not concerned with privacy issues. Lastly, while in open discussion the team proceeded to ask the interviewees if they personally have experienced any inconveniences when parking. It was interesting how both interviewees claimed

that finding availability of a vacant parking slot was a challenge. They suggested that connecting the parking complex data with a map and increasing accuracy on vacancy detection would be a short-term improvement.

4.3.6 Interview with Research Hangzhou Dianzi University Smart City Research Center

The sixth team interview was with the graduate students working at the Smart City Research Center of Hangzhou Dianzi University. The students interviewed, Min Shi and Ruiqing Qiu, had a comprehensive understanding of indoor localization methods and parking space prediction. The students introduced the project team to iBeacon, the Bluetooth technology developed by Apple Inc. The students have created a portable device that utilizes this technology. They informed the team that by installing several portable devices across a parking lot, parking lot users could use a Bluetooth connection to achieve accurate vehicle localization while inside the parking lot. The students believed that iBeacon will become a trend in the future due to its low cost and easy deployment. Similarly, the research students claimed that 5G may become the mainstream technology for its low cost and high capacity, as it improves human to human and human to object communications.

Additionally, the students recommended the project team focus more on the costs of hardware and extensibility of software frameworks when it comes to the development of a solution. When asked about the main issues with the parking systems in Hangzhou, the students stated that the major problem was the need for management personnel in parking lots. They believed an ideal system would be free all labor forces in order to reduce operational costs. As for the vehicle navigation methods within the complex, the students considered having a display board to the public as a valid solution, but also stated that there are people who have been working on a software solution for parking space navigation. The software solution will keep vehicles separated more evenly in the parking lot, instead of occupying spaces in a single area. Finally, the graduate students mentioned that people will usually accept new technologies if they work properly, but technologies that work poorly and have a high cost, result in the general public being reluctant to accept the change.

4.3.7 Summary of Industry Expert and Graduate & Research Student Interview Findings

The interviews performed gave the project team a variety of data due to the diverse occupations and focuses of the interview subjects. The format of having questions guide open discussions led the team to insightful data points that otherwise may not have been obtained through concrete interviews. The team was very fortunate to have the opportunity to interview and discuss future smart parking solutions with the interview subjects. Table 5 displays the compiled coding themes from the transcribed interviews. The three most prevalent themes throughout the interviews were Hardware Technology, Availability, and Social Idea.

Interview Coding Table							
	Alibaba	Hangzhou Pshare Tech Co.				Researcher & Graduate Students	
Themes	Shuai Li and Li Yuan	Jie Lu	Zhanyi Shi	Weijie Li	Hongcheng Shen	Min Shi & Ruiqing Qiu	Theme Total:
Availability	2	1	1	1	2	1	8
Convenience	1	1	0	0	1	0	3
Hardware Technology	0	4	4	4	1	3	16
Payment Method	2	0	0	0	0	0	2
Price	0	0	0	0	0	2	2
Safety	0	1	0	1	0	0	2
Social Idea	4	1	2	0	3	4	14
Software Technology	0	0	0	1	0	2	3
Interviewee Total:	9	8	7	7	7	12	

Table 5: Industry experts and research & graduate students interview coding table

Hardware technology occurred the most throughout the interviews, with 16 responses related to hardware. Hardware technology was a theme that the project team anticipated to appear very frequently, as a large portion of the interview questions pertain specifically to the hardware of smart parking systems (due to the sponsor's interest). As recorded in the interview transcripts in Appendices J and K, it was a common response that 5G and RFID were technologies that had potential in future smart parking solutions. Many interview subjects familiar with 5G technology stated that the technology had a low cost, with a high capacity and efficiency. Multiple interview subjects suggested 5G to be a technology capable of handling many of the current issues with smart parking systems in Hangzhou, China, as the technology has the ability to communicate with a mobile device.

In addition, RFID technology was a hot topic of discussion amongst many of the interviewees. RFID technology was a large focus of the project sponsor as it was very cheap and standardized in many automotive services around the globe. Many of the interview subjects felt that RFID technology had a potential for future smart parking solutions, as they had researched parking solutions that used RFID as a main form of identification. Along with 5G and RFID, a theme amongst the experts at PShare and the graduate students at HDU was that many technologies used in tandem have the greatest potential to effectively improve the current parking solutions in Hangzhou. Most of the PShare experts mentioned that while OCR cameras were currently widely used in Hangzhou, they estimated that they would be obsolete in future solutions. This was an important takeaway for the project team, as stated in section 4.1, many of the current systems in China mainly used OCR cameras for vehicle identification.

The second theme which was prominent in the interview responses was Social Idea. The Social Idea theme consisted of any social idea or concern that was relevant to the project team's research for a characteristic town's smart parking solution in Hangzhou, China. The interview with the employee form Alibaba brought light to the mindset that industry leaders have when thinking about the user experience of their technology. When asked about the personal data that Hangzhou's citizens would most likely accept new technology obtaining, the employee responded with "anything". He proceeded to explain to the team that in Hangzhou, as long as the technology worked well and was a low cost to the user, then Hangzhou's society would accept the technology. The consensus from many of the interviews was that if Hangzhou implemented new technology, it needed to be convenient and work well. This was one of the most important trends witnessed by the project team throughout the performed observations and interviews, as it signified that the team needed to consider the overall convenience of the smart parking solution.

Many of the interviews also encompassed discussions around the observed mobile device prevalence in Hangzhou. Hangzhou's society had become accustomed to using their mobile devices for nearly everything, and thus it had become the primary payment method across Hangzhou. The mobile payment methods are such a social normality that cash appears to be nearly obsolete. The team made a point to draw attention to the idea of the smart parking solutions payment method and navigation interface to be located on a mobile application. This idea led the interview discussions to the concept of diverse technologies working together to create a smart parking solution capable of the desired functions. The experts from various fields

at PShare specifically were in agreement that one technology would not completely resolve the current issues in Hangzhou's smart parking solutions. This agreement supported the project team's decision to research various technologies that could work together to create a smart parking solution for the characteristic town, as the CEO of PShare even stated:

"I think one technology cannot solve all the requirements. That is why I think many technologies should be used".

The last theme amongst many interview responses was Availability. This was a major topic of discussion due to the influx of registered vehicles that was exposing the weaknesses of the current parking systems (section 2.2.1 describes this issue in detail). The recent large influx of registered vehicles in Hangzhou led to many parking complexes becoming cluttered and inefficient. In turn, availability became a major focus area for researchers and developers of smart parking solutions as they needed to address the growing society's need for more parking spaces. When asked what data would be the most important in a future smart parking solution, the interviewees commonly expressed that the available parking space count was the most important. Not only did they signify the importance of the data for a system, but they also stated that this was of large importance for the customers. The hardware engineer of PShare specifically explained that this data could improve overall system efficiency by attracting customers when there is vacancy, and turning customers away when the complex is full.

Many of the discussions with various employees suggested that a parking complex could offer more efficient parking by taking into account the times that routine users park. The interview subjects suggested that a parking complex could use artificial intelligence to offer parking spaces for customers based on the time that they would need it if they were a routine customer. For instance, if an employee of the project's IoT town only needed parking from 9am-5pm, after 5pm the system could offer that parking space for a nearby resident that needs a parking space for the night. This important suggestion is an example of ideas researchers are developing to improve availability within a densely populated city such as Hangzhou.

4.4 Conclusion of Consumer and Provider Needs

From the three separate methods of data collection, the team drew parallels to suggest the top consumer and provider needs for the recommended smart parking solution. Using the

recurring trends in collected data, along with recorded shortcomings of the current system, the team created a list of focus areas to guide research for potential technological solutions applied to smart parking. By considering the needs of both consumer and providers, the project team assembled recommendations favorable to both parties.

4.4.1 Improved Availability and Vacancy Identification

A major area of focus that the team's three separate data collection methods highlighted was the need for a more effective parking spot availability and vacancy identification method. As previously mentioned, the team conducted surveys at four separate parking complexes. The parking complexes which the team visited which have LED lights above each parking space proved to be inconsistent when using OCR cameras as a sensing technology. The survey results at the complexes using these LEDs displayed that a large portion of customers felt the technology was insufficient, making it difficult to find an available parking spot. The OCR cameras were incorrectly marking spots as vacant or available which caused inconveniences for the consumers. This in conjunction with the fact that nearly half of the interviewed customers felt the technology applied in these parking complexes was sufficient depicted a trend of inconsistency in customer satisfaction with the technology.

The survey results from the parking complexes which did not utilize the LED indicators solidified the team's belief that there is a prevalent consumer need for improved vehicle identification methods. When looking at the entirety of the data across all four survey locations, the team realized that there were nearly equal responses stating it was easy and hard to find available parking spaces. The fact that the data collected was nearly equivalent between the different survey locations proves that consumers truly feel that the malfunctioning sensing technology increases the inconvenience of finding an available parking space. The need for improved availability and identification methods directly relates to the customer needs of increased efficiency for smart parking systems.

The data obtained from the administered interviews qualified the observed and recorded needs. All three demographics of interview subjects had responses which touched upon the current issues of marking available parking spaces, and the associated lack of direction to these spots. Considering that both industry experts, and consumers are aware of the need for a more effective system, the team confirmed that the vehicle identification and directional system to

available spots will be a major area of development in the proposed recommendation to improve the overall efficiency.

4.4.2 Convenient Solution

Upon review of the observation, survey, and data results, the project team immediately saw a clear and distinct trend that technology needed to be convenient in Hangzhou in order for Hangzhou's consumers to accept it. The data collected particularly signifies the importance of convenience to Hangzhou's citizens. The interviews primarily revealed this need of consumers, as the interview transcripts in Appendices J-P depict multiple interview subjects that made statements supporting this need. An example of these statements is a direct quote from the graduate research students, stating: "when a technology is working perfectly, the public will usually accept the technology. However, when it works poorly or have a high cost, the people will less likely to accept the technology". It is important to note that the 'public' described in this quote, is the people of Hangzhou based on the context of the response and previous discussion questions. This quote and similar statements in the interview transcripts support the data from the observations and surveys, as there were trends in the results displaying customers being unsatisfied with the technology if there was any sort of inconvenience (described in detail in section 4.2.4).

The need for technology to work well and convenient for consumers was also a need for providers, as the visited current parking systems in Hangzhou had large amounts of management personnel (excluding Huawei). The management personnel staff was rather large at all of the facilities, consisting of three or more individuals. These individuals were there to monitor the safety of the parking facilities, but also were administrators of the parking systems. The parking complexes with smart systems had their sensors wires feed into a central terminal that had a physical lock on it. At Huawei it was clear the complex operated efficiently and more advanced than any other witnessed system. There was one management personnel located at a desk for observation and customer service. This suggested to the team that a more convenient and efficient solution could indeed cut management personnel, which was a goal of the project sponsor. The collected interview data includes expert opinions stating potential for future smart parking solutions interfaced to the cloud, which could allow management personnel to position at

a remote location and monitor multiple parking complexes. This would reduce management personnel and severely cut maintenance costs of the current parking solutions in Hangzhou.

4.4.3 Mobile Device Integration

One commonality noted while observing the six parking complexes across Hangzhou was the fact that all complexes accepted mobile payment methods such as Alipay and WeChat Wallet. This not surprising given that Hangzhou has adopted non-contact payment methods as a social normality, more so a part of everyday life. Simply put, opting to use alternative payment methods appear inconvenient in the eyes of Hangzhou citizens. The interviews conducted while at Alibaba consisted of discussion mostly targeted toward future payment methods and user experience. The interview subjects mentioned that mobile payment methods are necessary in the success of a business model in Hangzhou and that there is extensive research on future payment methods. There were two major inconveniences recorded during the observation period. Customers at each of the parking lots had to interact with a personnel member to pay with their mobile payment account, or scan a QR code located on the walls of the parking complex. This required significant extraneous time spent throughout a customer's interaction with the smart parking systems. The interview subjects at Alibaba mentioned there is research conducted to remove the need of a mobile device from non-contact payment methods, but these new payment technologies take significant time to develop. During informal discussion, they offered the fact that there has been significant efforts to remove the need for third party applications, and create more universal mobile payment options. This information, along with the customer interactions witnessed at the parking complexes allowed the team to infer the consumer and provider need for further developments in the efficiency of mobile payment methods used within smart parking complexes. Addressing this need would allow for a streamlined experience for customers, saving time and improving customer satisfaction. Moreover, improved mobile payment solutions have the ability to minimize the amount of required personnel employed by providers.

4.4.4 Improved Communication Technologies

Immediately upon entering all six observation locations, the project team witnessed the OCR cameras used at the access level of the parking complexes. OCR camera technology used at the entrance and exit barriers allowed a vehicle through based on whether the vehicle was

registered or unregistered in the system. In the more modern smart parking systems, OCR cameras identified the vacancy of a parking spot. The OCR system transferred infromation to a database that updated counters placed within the facility which displayed the total number of available parking spaces. The project team discovered the OCR cameras to have a large amount of error, as there were many spots incorrectly marked as vacant or occupied. This led the team to believe that the OCR camera technology was not working effectively, especially in comparison to the technology used at the Huawei parking complex. Huawei's parking complex had ultrasonic sensors above each parking space that generated zero error in vehicle detection. This illustrates the effect improved technology could have on the current smart parking complexes, as the errors witnessed in OCR camera technology were not present in the ultrasonic technology.

Many survey subjects identified the technology as inefficient in a parking complex when it was difficult to find available parking spaces. This produced a large amount of customer dissatisfaction with the current technology to display available parking spaces in Hangzhou's smart parking systems. The interviews with industry experts and graduate research students suggested improved communication technologies to address the challenges of the current parking systems. Many of the interviewed experts suggested using 5G and/or RFID technology in future smart parking solutions. Interview subjects recommended 5G as the current research of the technology indicates that it is of low cost and vast potential applications. Additionally, experts considered RFID as it is widely used in other countries, and thus has significant research backing its applications.

These key data points from the data collection led the project team to the overall need of improved communication technologies amongst the smart parking complexes. A more reliable technology with increased capabilities could address the current errors displayed in OCR camera technology. Technology with increased capabilities such as 5G and RFID could connect to the cloud for real-time monitoring and administering.

4.5 Research of Potential Smart Parking Solutions

The consumer and provider needs derived from the analysis of the team's three data collection methods directed the research of potential technological solutions for the IoT town smart parking. The following section consists of technologies revealed during the observation and interview processes, which have the possibility of aiding the shortcomings of the current systems. The team researched technologies which interview subjects recommended and those discovered during general project research. The following sections evaluate each individual technology for its ability to meet the consumer and provider needs.

4.5.1 Fifth Generation of Cellular Mobile Communication (5G)

As stated by the industry experts and graduate research students in Chapter 4.3, the Fifth Generation (5G) of cellular mobile communications has great potential for the future of smart parking as it is easily applicable to current IoT infrastructure. China acknowledged 5G as a future solution and thus has begun extensive research of the technology in hopes of beating the United States and being in the forefront of smart city development (Downes, 2015). Research in 5G has suggested that the technology supports a higher data transmission speed, reduced latency, lower operational and energy costs, and more bandwidth than many modern communication technologies. Due to these anticipated capabilities, the technology has the ability to connect many more devices together. Many researchers are looking at 5G as an underlying technology for future IoT solutions. Currently, 5G is still under development and researchers claim it will launch in the year 2020 (Goldman, 2018). Figure 25 illustrates the attributes of 5G technology.

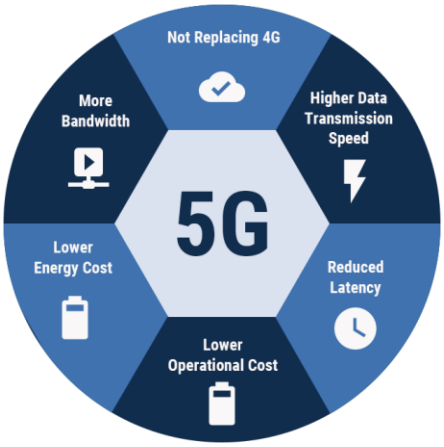

Figure 25: Attributes of 5G technology

5G technology creates various new opportunities for IoT based technology as it opens a spectrum for a new range of frequencies (millimeter waves) to connect massive amounts of devices. This is important to smart parking as 5G could connect sensing technologies wirelessly and allow them to have more bandwidth per device. With estimated billions of devices connected to the network in the future, 5G has the potential to transmit vast amounts of data among sensors, cars, and new smart technologies. This is a big advantage for smart city developments because it allows various device types to communicate with each other more effectively. Even though 5G is ten times faster than 4G it will not be replacing it. Instead, it will work alongside the current 4G system to improve the connectivity and data transfer speeds all devices.

5G technology works at higher frequencies called millimeter waves, operating in the 30 to 300 GHz frequency spectrum. A large downfall to these waves is that they do not easily travel through walls or obstacles (Rouse, 2015). Thus Narrow Band Internet of Things (NB-IoT) technology works in tandem with 5G to penetrate multiple stories underground (Chaisatien, 2016). This is an advantage for 5G since current 4G cellular communications signals cannot communicate with mobile devices while underground. 5G underground cell phone service creates the possibility of connecting mobile devices with additional smart parking technologies. The small cell towers that 5G utilize require minimal power and their smaller size allows them to easily deploy in current facilities.

The estimated low latency of 5G will allow fast responses to demanding processes of a smart parking system such as vehicle reservations, real-time system updates, and remote administration. 5G leverages network splicing to deploy and allocate virtual networks for system tasks, thus allowing for task priority within a system (Downes, 2015). Task priority is a process that enables crucial tasks to transfer data faster than 'less important' tasks. This allows engineers to design a system with the ability to operate efficiently based on system requests that should be extremely fast. In the context of smart parking, this capability will minimize the chance of two users reserving a specific parking spot at the same time. This is a benefit over current systems, as engineers can improve system design to increase the customer experience and overall satisfaction.

5G is applicable to an array of sensing technologies and mobile device features within smart parking. The low cost and adaptability of the technology make it an extremely enticing solution for developers of smart technologies. 5G communication enables OCR, infrared sensors,

and similar sensing technologies to be completely wireless. This further mitigates the need for additional personnel within parking complexes as a cloud platform could connect many devices. Due to 5G being still in the research and development phase, the project team was unable to find applications of 5G applied to smart parking. This does not pose a concern for the project, as the final recommendations scope is a future smart parking complex.

4.5.2 Radio Frequency Identification (RFID)

Through the observations and data collection methods discussed in section 4.4, the team believes that passive RFID tags are not feasible at entrance gates in future smart parking solutions when distributed in card form. Using passive tag cards requires the user to put the tag near a gate scanner, which when applied to smart parking wastes valuable customer time. For this reason, the team opted to further research long-range RFID solutions which use passive, active, and semi-active technologies.

Considering the fact that the IoT town has two separate demographics, employees and visitors, the team more specifically focused on the differences between the application of passive and active tags. In terms of long-term parking residents such as employees, it is logical that the IoT town would justify more costly active tags. Companies such as Gao RFID offer both passive and active RFID systems for parking complexes. Their offered solutions applicable to the IoT town consist of 900 MHz high frequency (HF) passive tags capable of reaching five meters, and varying frequency active tags capable of reaching 30 meters. Besides communication range, the major difference between both systems is the price per tag.

Gao presents the high-frequency passive tags as being applicable to parking complexes utilizing a common gate system to verify incoming vehicles. In application, Gao states that the 900 MHz tags are capable of being applied to the front of the vehicle, such as the windshield, and register with a tag reader located at the security gate. The team found that five meters is sufficient for recognizing the first vehicle in queue at the gate, without reading the tags of vehicles potentially waiting in line. While the project sponsor indicated that cost is less of a concern for the system design, the team suggests the use of passive RFID tags as they are cost-effective and streamline access to the parking complex.

When providing examples of their active tag systems, Gao describes a system where truck drivers gain automatic access through large gates from a distance. This system completely

mitigates the need for stopping and allows for the highest levels of traffic mitigation coming into the complex. The active tags they offer are significantly larger in size and operate at either 433 MHz or 2.4 GHz. Considering the tag requires a powered transceiver, the overall cost per tag is more expensive. Gao notes that active RFID tags allow for real-time monitoring of movements, but require supporting software and localization systems to properly operate. In applications that require the 30-meter read range, active tags are a reliable system for user identification.

In application, both RFID tag types are potentials for future smart parking solutions. Active and semi-active tags are overkill for most applications within parking complexes, yet easily adapt to many other facets of the automotive industry. Considering the consumer needs of utilizing convenient and economical solutions, high-frequency passive tags are sufficient to meet system requirements and control the overall system costs. When considering smart parking systems which incorporate validation gates at the entrances of the complex, HF passive tags streamline the process without the unnecessary cost and features of active tags.

4.5.3 Bluetooth

Bluetooth is a widely used technology, known for its high transmission rate and long physical range. Many smart parking solutions use Bluetooth as either the method of communication between sensor nodes or as independent vacancy identification modules. During sponsor facilitated interviews the team witnessed two Bluetooth based parking solutions currently in development. While at PShare Co., the CEO of PShare demonstrated their Bluetooth parking lock technology. Users can use a dedicated smartphone application to scan the QR code in the parking lock to pair it with their smartphone, as seen in Figure 26. After parking, users will be able to control the lock's status through a Bluetooth connection. The users can also share the pairing key with other users, giving them temporary access to the parking lock. This solution mitigates the need for security personnel seen manually unlocking parking locks at the Qianjiang New Town Time Square parking complex.

Figure 26: PShare lock with QR code for smartphone pairing

The graduate research students exposed the project team to a new form of Bluetooth called iBeacon; a connection protocol module developed by Apple Inc. iBeacon devices have a relatively low energy cost and a long broadcast range. When deployed, they will broadcast their device information periodically. Smartphones that discovered the broadcast will be able to acquire the distance of the device, and read the information transmitted by the device. By determining the signal weakness of the devices, iBeacon has indoor localization capabilities. The true strength of iBeacon lie in the fact that the solution relies on customer mobile devices for validation and reservation, rather than complex sensing technologies. Mitigating the need for applied sensing technologies drives down the cost per parking space of the necessary technology. In the case of iBeacon, less technology tends to prove effective in comparison to current vacancy identification techniques. iBeacon is a prime example of smart technology that relies on less complex hardware, when developers use it in tandem with innovative software solutions.

As a whole, research demonstrates that Bluetooth applied to smart parking is a successful method of communication between sensing modules. In Denver, Colorado the company Parkifi has been extremely successful deploying a citywide parking plan consisting of Bluetooth connected electromagnetic sensors (Rawlins, 2015). The system has sensors installed below the street level, which allows for customer's to mark the spot as occupied. Parkifi's use of Bluetooth technology is highly effective, as they chain the devices together to create a complex network which ultimately sends vacancy data to an IoT platform. This data is easily accessible by customers, as they are able to access a map marking available spots throughout the city. In terms of Parkifi's solution, the use of electromagnetic sensors as a form of vacancy identification

allows for the system's integration in a complex network system spanning across the city of Denver.

While a variety of industries apply Bluetooth technology, it comes with inherent shortcomings. Smartphone users typically turn Bluetooth off when not needed, as it has a high energy consumption. Certain users may even find turning Bluetooth on themselves is an inconvenience. Promoting the usage of Bluetooth for a solution can be a tough task if users find it inconvenient.

4.5.4 Infrared Light Sensors

Active infrared sensors make use of a ray caster and a receiver to recognize changes in its surroundings. When applied to a vacant parking spot, receivers collect a majority of the light casted. However, the vehicle will block the light path to identify a parking spot as occupied, preventing the receiver from receiving full signal, thus transmitting information about the parking spot availability. Systems can incorporate active sensors without an additional receiver module, as they rely on the collection of reflected infrared light. When used in parking, a car located in a parking spot will reflect significantly more light than when the infrared light travels toward the ground in a vacant parking space.

Passive infrared sensors make use of the infrared emitted by the surrounding objects. These sensors have a fairly short detection range, but are capable of capturing the temperature changes. When a major rise in temperature occurs, the sensor can determine the parking spot as occupied and vice versa. In comparison to the active infrared sensor, the passive sensor has a much lower cost. However, both type of sensors can malfunction during non-optimal weather conditions. For example, active sensors might not work in a dense fog condition, and passive sensors might not work when the temperature is high.

An article posted by the company SmartParking on October 29th of 2014 illustrates the launch of a smart parking system in Westminster, London. The smart parking system utilizes infrared sensors to detect when a vehicle occupies a parking space. An RFID beacon then transmits the information to a database. By updating a cloud platform every minute, the system offers near real-time information of available parking spaces on a mobile device platform. Westminster deployed over 10,000 SmartPark sensors across the city after its tests proved successful in other countries. This marks the world's largest deployment of real-time parking

technology as of 2014. Councilor Heather Acton, Westminster City Council Cabinet Member for Parking & Sustainability commented that SmartPark was “making it easier to find a parking space, and reducing congestion in the process, the sensors are a key investment in Westminster’s commitment to provide ‘fair, easy and safe parking’” (SmartParking 2014).

The team assumes infrared sensors to be more reliable than OCR cameras because they use physical sensing of transmitted waves instead of digital sensing methods. There are no inherent risks regarding the public's acceptance of the technology, as many industries already apply the technology. The low price for the technology could reduce the overall cost for a parking complex, thus further reducing customers’ cost for parking.

4.5.5 Ultrasonic Sensors

As discussed in Chapter 2.3, Parking Guidance and Information Systems (PGIS) assist drivers to available parking spots, as seen in Figure 27. Smart parking systems use ultrasonic sensors to detect vehicle spot occupancy using sound waves. The installation of ultrasonic sensors is non-intrusive, meaning that there are no major infrastructural changes to parking complexes. The usual placement of these sensors are on the ceiling above the parking space, accompanied by a LED enabling users to easily distinguish a vacant spot. In order to sense the vehicle, the ultrasonic sensor transmit a sound wave (25 kHz-50 kHz) which reflects off the vehicle or the ground back to the sensor. Then the time difference between the emitted and received wave determines if a parking spot is vacant or not (Kianpisheh, 2012).

Figure 27: PGI system that implements LEDs with ultrasonic sensors to determine vacancy (Hiphen, .n.d)

A benefit of ultrasonic sensors is that their history of applications depicts them as a reliable sensing technology. The sensors are insensitive to factors like light, dust, smoke, mist, vapor and lint (Burnett, 2018). The reliability and consistency of these sensors enables their use in both indoor and outdoor applications. The only factors that affect ultrasonic sensors readings are temperature and air turbulence, but in controlled environments such as underground parking complexes this is less likely to occur (Kianpisheh, 2012). Another benefit is the low cost of these sensors. Unlike other sensors, ultrasonic sensor can be one of the most reliable and cost-effective solutions for large scale parking complex.

Many automotive solutions currently use ultrasonic sensors for object detection, distance detection, anti-collision detection, and automated parking. The wide use of these sensors proved valuable to the global demand for this low cost device that provides additional efficiency and safety to systems (Clare , 2016). Due to a high global demand, ultrasonic sensors became well-developed and proved to be useful in their various applications. MSR-Traffic is an international company that develops sensor technology for indoor and outdoor PGI systems. In Stadtgalerie Passau, the largest shopping mall in Passau, Germany, MSR-traffic deploys ultrasonic sensors for vacancy identification in their systems. MSR-traffic mentioned that before the installation of this system in the shopping mall parking complex, visitors were not able to determine if a spot was available or where the nearest free parking space was. The installation of the PGI system increased the overall system efficiency. This was a crucial to the shopping complex since a less congested and easy to navigate parking complex provides a more relaxed shopping experience, satisfying the customer needs for convenience (MSR-Traffic).

As discussed in section 4.1.6 the team visited the Huawei smart parking complex because Huawei is similar to the IoT characteristic town. In this smart parking system, the complex positions ultrasonic sensors on each individual parking spot to determine vacancy. The use of the ultrasonic sensors above each spot proved to be reliable since the team spotted no apparent error in the system. With a robust system like this, the need for less personnel made this parking system the most efficient of the six observed by the team. This is ideal since the users of the parking lot can easily find vacant spots in this parking complex.

4.5.6 Electromagnetic Field Sensors

Smart parking systems typically install electromagnetic sensors on the ground to detect nearby vehicles within a parking space. Section 2.4.4 further explains the technical capabilities and how they register vehicle presence. A large benefit of electromagnetic sensors is that research depicts their performance as reliable. These sensors prove versatile in all weather conditions, while some other sensing technologies can be extremely sensitive to environmental changes. This factor supports the application of electromagnetic sensors as excellent choices in smart parking systems with outdoor parking spaces. Unfortunately, this benefit is negligible for the IoT town's parking system because the ability to work efficiently in many weather conditions is not very important in underground complexes. Another large benefit of electromagnetic sensors is they can be very small and completely wireless. This allows the deployment of easily maintained sensors. A large downfall of the electromagnetic sensors is their high price compared to many alternatives. When deployed on a large scale across parking complexes with many parking spaces, this cost per unit can quickly become expensive. Fortunately for the IoT town, the cost for the initial system design is out of scope and less of a concern.

ParkiFi is a company that offers a smart parking solution with electromagnetic sensors as their main form of sensing technology. The sensors are roughly the size of a hockey puck with a magnetometer inside. The magnetometer senses metal in a vehicle and transmits the data to a communication network. A disposable battery limits the sensors life, because they need replacements every five years. A large scale implementation of ParkiFi's system has increased parking efficiency for the town of Denver, Colorado (ParkiFi, 2018). Nwave sells a very similar solution with identical hardware, however they market their solution on the idea that their Nwave specialists service the entire backend software administration for customers. This reduces the need for parking complex owners to hire extraneous personnel to monitor and update the backend software. This allows for increased longevity of the overall user experience as the solution always has dedicated support (Nwave, 2018).

The research conducted suggests that electromagnetic sensors are a phenomenal wireless solution for small to large scale outdoor applications. There has been significant research and development of the sensors that has led to multiple startup companies. ParkiFi deployed these sensors in their citywide solution for Denver because of their reliable accuracy in detecting a vehicle's presence. For an underground parking complex solution designed for the IoT town, the

major benefits are that the sensors are accurate and wireless. These two characteristics support the consumer and provider need of a convenient solution, as well as the need for improved availability and vacancy identification. The accuracy and overall lifetime of a sensor would enable the smart parking solution to have real-time data displayed to the consumer with minimal error compared to OCR camera technology. Additionally, the electromagnetic sensors can integrate to a cloud database for monitoring, administration, and mobile device integration.

4.5.7 Electronic License Plate

Industry experts in China have developed beliefs that government involvement will result in the widespread use of electronic license plates to replace the current methods of vehicle identification. The potential of additional applied smart technologies to the current vehicle registration process opens up the door for the integration of electric license plates within smart parking. Electronic license plates use RFID technologies or other IoT applicable technologies such as 5G. Currently, most research points toward the use of RFID as the main form of communication for digital license plates. These license plates and the RFID scanners usually have much longer range than regular RFID tags, as vehicles move in high speed on the streets. The use of semi-active and active RFID tags allows the scanner to reach distances upwards of 40 meters, and recognize vehicles running as fast as 100 km/h. Unlike the use of traditional OCR cameras, RFID scanners do not rely on shutter speed - meaning they can still capture a clear record of vehicles under high speed or vehicles in poorly lit areas. In 2018, the Chinese government started to promote electronic license plate officially, running experiments in Beijing, Shenzhen, and Wuxi. The license plate contains license plate information as well as vehicle statistics such as geological locations and current speed. The license plate allows vehicle owners to complete transactions at the parking lot in rapid speeds. Government officials believe that the introduction of the electronic license plate will reduce the occurrence of vehicle crimes, such as thefts or speeding.

The introduction of the electronic license plate does not necessarily mean traffic cameras will become obsolete. According to the Jiangsu Province Police Department, the cameras will still capture and record images of vehicles that break the law. The interviews with PShare expressed that electronic license plates will likely replace optical camera recognition. Guangzhou Tianzhi Intellective Co, Ltd has been researching electronic license plates. The company installs

electronic license plates on vehicles, and use a long-range RFID scanner to read vehicle identification data. A database records authorization data, and authorized vehicles with electronic license plates can pass through toll gates without having to stop or slow down. On the other hand, unauthorized vehicles will need to stop and allow the OCR camera at the gate to read vehicle identification information. The system logs vehicle entry records to the console, further reducing the chance of crime. With the introduction of electronic license plates, parking lot entrances and exits will run much more effectively as the camera identifies customers seamlessly.

The development of electronic license plates has created a new platform for the application of more modern communication technologies. While RFID has proved to be extremely effective when applied to automatic tolls, the development of 5G technology may result in a standardized system of vehicle identification and management in China. While there is no formal information released on the application of 5G for electronic license plates, the project sponsor has suggested that there is great potential of it becoming a reality upon the deployment of 5G.

4.5.8 PShare Smart Parking Locks

The team received an informal presentation of PShare's current smart parking solutions during a sponsor facilitated site visit from the CEO of PShare, Hongcheng Shen. Their current products focus on smart locks that easily install into individual parking spaces (Figure 28). These locks act as physical barriers for both electric vehicle stations and traditional parking spaces. The barrier currently receives Bluetooth connections from mobile devices or an auto sensing controller (developed by PShare) with a unique access code to grant entry to the permitted vehicle. In order to register and determine the presence of a vehicle in the space, the locks have individual infrared or ultrasonic sensors installed within the device. If a vandal tampers with these locks, they provide extra security with an audible alarm and a backend software alarm that alerts the complex owners. In a smart parking system, these locks currently use wired RS458 or wireless Zigbee to communicate.

Figure 28: PShare-01ZU parking lock with Zigbee capability (PShare, n.d.)

PShare provides locks that are fully automatic. Their PShare-01A model is an example of their current generation lock that uses an auto sensing controller in the car and the Bluetooth parking lock. The third-party PShare app controls the lock. These two communication technologies enable the lock to identify the presence of an approaching or exiting vehicle.

PShare developed the PShare-01BU model specifically for private parking sharing. This lock enables the use of the app and cloud platform to for an intelligent parking sharing platform. This enables users to book, navigate and pay for the parking space all in an App connected to the cloud. There are two types of models for these private sharing locks the 01BU and 01B. The difference is that the 01BU is able to monitor the vehicle. This means that when a vehicle leaves the parking space, the lock will rise up after two minutes. For the 01B model the user is required to click the app after two minutes after the car leaves the parking space.

PShare developed their PShare-01RU model for use with charge piles for electric vehicles. The 01RU model has a RS485 wired connection that allows for a more reliable and safe connection according to PShare. It also enables the lock to be cheaper as battery replacement becomes unnecessary. The user of the charging pile can control the lock and pay through PShare's Charge Pile App. The 01BU model also has the capability to connect to the charge pile by installing the BXB-02 embedded circuit. The BX-02 gives the charging pile the capability to connect to more than one parking lock.

PShare made their PShare-01ZU model for parking complexes of all sizes. The 01ZU lock has the capability to communicate with PShares intelligent gateway hardware that uses Zigbee. This factor allows for the scalability of a smart parking system utilizing the 01ZU lock. A system like this can adapt to the size of many parking complexes. Another factor is the remote allows the ability to monitor, control, and support the incorporation of a WeChat public number. This lock is easily adaptable to many of today's complexes since parking space is an issue and many parking complexes have various sizes.

With the locks' success, PShare has been able to install their parking solution in Sydney, Nantong, Shanghai, and Hangzhou parking complexes. The team was able to observe the locks at PShares headquarters in Hangzhou and the advantages the lock brought to a smart parking system. The most notable benefit of this lock was the convenience it brought to the customer by saving time and effort. The potential for this technology is vast due to its intuitive app interface, Bluetooth capability, and cloud platform. The modularity that this technology brings to a parking complex allows for little infrastructural change (PShare, n.d.).

4.5.9 Biometric Authentication

In section 4.3.5, Alibaba expert Shuai Li mentioned the company's goal was to use biometric payment methods in the future. Biometric payment is a form of authentication of an individual based on unique biological characteristics. There are various forms of authentication such as retina scans, iris recognition, finger scanning, finger vein ID, facial recognition, and voice identification (Rouse, 2014). In order to verify the user, the system compares the biometric data captured with encrypted information stored in a database (Rouse, 2006).

One of the major benefits of biometric data is it is difficult to falsify. This provides users long-term conveniences, such as not having to use numerical passwords. In societies such as Hangzhou's, streamlining payment methods is extremely enticing to consumers. No longer relying on numerical or alphabetical passwords minimizes the amount of time consumers spend interacting with payment systems. These benefits, while safe and convenient, come at a high cost. While the IoT town is not necessarily concerned with system costs, biometric data systems are still developing and require the government's support to be pushed into use in the near future. Reducing the costs of these systems will make them more applicable to multiple industries, and inherently more desirable to develop. Furthermore, the complexity of biometric authentication

can lead to some error in the identification of a customer. This is similar to OCR cameras and how the complexity of such technology can have a negative effect on a parking system.

Alibaba is one of the tech companies pushing biometric payments for a better customer experience. The company has integrated Etron's 3D wide angle recognition modules into their unmanned store in Hangzhou, China for facial recognition (Burt, 2018). This payment system consists of scanning the Alipay QR code and the customers face when entering the store. After shopping, the customer can freely walk out of the store with automatic checkout services (McQuarrie, 2018). With biometric payment, Alibaba's goal is to satisfy their customers by making the purchasing experience almost seamless. The use of an individual's characteristics allows for a device-less transaction that minimizes the time for conducting a purchase and makes it more convenient for the customer. Alibaba has also partnered with the well-renowned hotel chain Marriott to implement their biometric authentication. Similar to the smart store, the hotel guest scans their ID, has their face recognized and then inputs personal data in order to retrieve their room key (Burt, 2018). This future technology could be crucial in the customer satisfaction since it would lower personnel management allowing for a more efficient and smoother overall experience.

With a future technology like biometric authentication, payment transactions could be convenient and economical. The device-less transaction could allow customers of a system to pay faster and could even cut on device costs. By properly identifying the difference between biometric identification and authentication, consumers could consider it as a safe and convenient way of payment.

4.5.10 Alipay Mini Apps

The WeChat development team first proposed the concept of a mini app. Mini apps are web applications integrated in a mobile application, such as WeChat or Alipay (Beijing Qingnian News, 2016). Thanks to the flexibility and compatibility of web pages, the applications can run on both Android and iOS systems properly with only one set of codes (Alipay, n.d.). Accessing a mini app only costs the user a small amount of data, as the mini apps are usually light weight. Some researchers argue that users can abandon the need for downloading an extra application on their smartphone by only using mini apps (Beijing Qingnian News, 2016).

Service providers such as ofo, Hangzhou metro or Didi all have integrated their mini app into Alipay, and the mini apps are fully functional with no difference to an actual standalone application (as seen in Figure 29). The Alipay mini app API even allows users to complete transaction with service providers without redirecting between applications, saving time in a fast paced society in China (Alipay, n.d.).

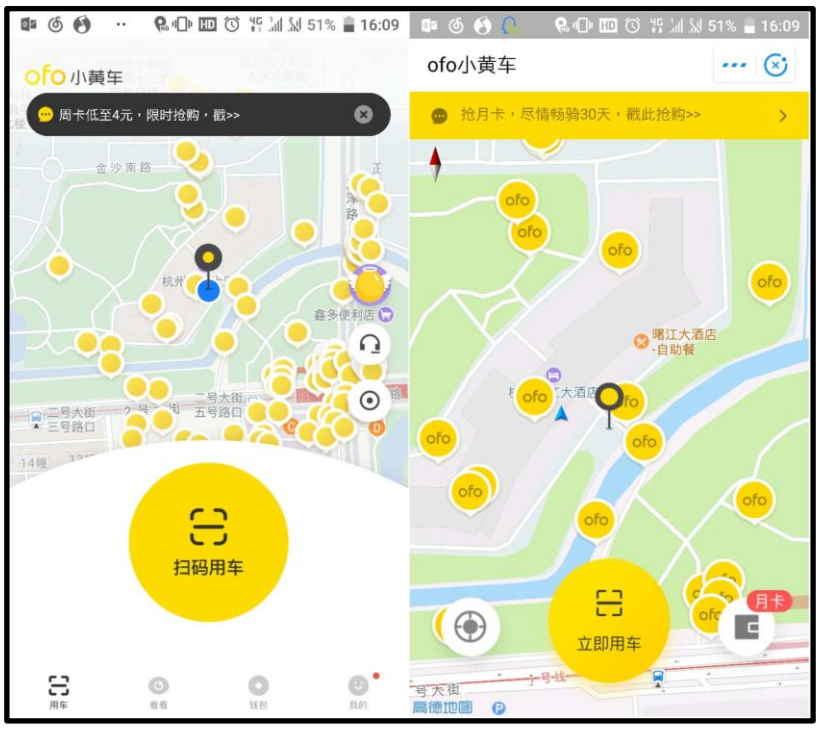

Figure 29: Left Ofo app screenshot, and on the right integrated mini app of Ofo in Alipay

The Alipay API documentation described the sockets open to developers, including user payment authorization, map display and even facial recognition. Alipay's mini app API also provided a connection method to scan nearby iBeacon devices and establish connection to it (Alipay, n.d.). As mentioned in section 4.3.6, the students in the Smart City Research Center of Zhejiang Province were able to accomplish indoor localization with iBeacon devices, but this requires a dedicated application to access the precise location. The team believes that a mini app that integrates parking lot information, vehicle navigation, indoor localization and automatic payment can drastically improve the effectiveness when parking or retrieving a vehicle.

JParking developed a wholesome parking solution by implemented their smart parking mini app into Alipay. With their mini application, vehicle owners can look up nearest parking lot information inside the mini app, and can authorize the mini app to automatically complete

transactions in parking complexes cooperated with JParking (JParking, n.d.). Parking lot managers have reported a massive increase in efficiency and reduce in the need for labor force after integrating their parking lot with JParking technologies (CSDN, 2018).

4.5.11 Smart Parking Systems and Technologies in Shanghai

Shanghai has an advanced parking system concept to support its massive population. This section expresses how Shanghai has overcome its lack of adequate parking area. According to Shanghai Parking Lot Regulation rule 28, a regulation announced by the Shanghai city government in 2013, the government requires all parking lots to share their service data with the city wide parking information database (Shanghai Government, 2012).

In 2015, Huawei partnered with Shanghai Unicom, a cell phone carrier company to implement Narrow Band Internet of Things (NB-IoT) into smart parking systems (Huawei, 2017). NB-IoT has a reputation for its low energy consumption and low cost (GSMA, n.d.). The companies installed parking vacancy detectors-connected them to the cloud using NB-IoT. The detectors report vacancy statistics at a rapid speed. Smartphone users can gain access to the system data, ultimately improving effectiveness on finding empty parking spots throughout the city. By the end of 2017, almost every parking lot connected to the network. Currently, vehicle owners in Shanghai can use a dedicated mobile application “Shanghai Parking” to find out whether a parking lot has available spots, and if so receive information on the price and location of the parking complex (Seven Traffic Net, 2017).

Smart parking is not limited to technology based parking systems. It extends to the smart way of sharing resources with the surrounding area. Shanghai city government assigned time slot-based shared parking spots inside private parking lots (China Central Television Finance, 2017). Each parking lot will become open to the public at a certain time of day when the parking lot is not flooded with vehicles. Figure 30 demonstrates how social vehicles can get parking lots using timeslot shared parking. Parking lots of companies and office buildings usually have less occupants during the night, while residential parking lots usually have less occupants during the day. The concept of parking sharing is to allow shared vehicles to park inside business parking lots at night and park inside residential complexes during the day (China Central Television Finance, 2017). The project team believes that this is a crucial idea to the recommendation of a

smart parking system, as the PShare expert also mentioned this method of using parking spaces effectively during the interview.

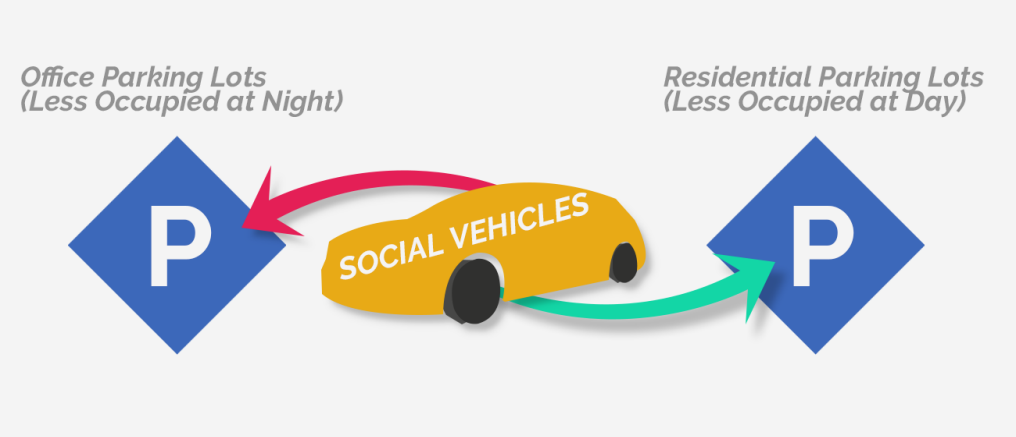

Figure 30: Shared parking concept of two parking lots

Shanghai has insufficient parking resources to support the population which caused shared parking to drastically improve parking spot availability and reduced time taken to find vacant spaces. With the significant increase in vehicles, Hangzhou is also facing the problem of having insufficient parking spots. Sharing parking resources can alleviate this problem and improve vehicle flow in both the parking lots and the streets.

4.5.12 Smart Parking Systems and Technologies in the United States of America

In the summer of 2011, Washington D.C. launched a pilot program for a smart parking solution. The smart parking solution placed two optical sensors in the asphalt and around parking spaces. The optical sensors would detect a sudden change in the darkness of a parking space. The sudden change indicated to the system an occupied parking space if both sensors detected a sudden change at the same time. The devices send the information to a transceiver in the area that collects data from roughly a dozen parking spaces. Each transceiver sends the data to a database that transfers the data to a central database. The database connected to an interface for administrators and a mobile device application for users. This pilot program saw such success that Washington decided to implement the solution citywide. The success of the project was largely because the sensors were accurate in detecting if a parking space was vacant. The accuracy and the wireless nature of the system allowed a cloud platform to administer and monitor the system, which eliminated the extra cost of management personnel for individual

parking locations. San Francisco adapted a similar system that they implemented across the city, known as SFpark. The city released the data to private companies developing smartphone apps because the data offered the ability to reduce overall traffic congestion in the city (Ross, 2011). While optical sensors would not work effectively in Hangzhou due to the underground nature of the complexes, these systems are important to this project as the systems have citywide deployments due to their effectiveness. The system was also completely wireless and the database was in the cloud, which allowed for real-time monitoring and access for both consumers and providers on many platforms.

In recent years, large amounts of smart parking research in the United States has been on automation. In an article from January 26, 2017, Ryan Citron of Forbes states: "The future of the smart parking market is expected to be significantly influenced by the arrival of automated vehicles (AVs)". Ryan continues to state that many cities are piloting self-driving cars and robotic parking lots. For example, ParkPlus in Colorado is working on deploying a fully automated parking garage across the Western United States. The system uses lasers to scan a vehicle and a robot then lifts and parks the vehicle for the customer. The system is then able to lift cars into spaces that traditional parking complexes would not have the ability to reach. The automation allows the available parking space to be extremely efficient and compact in space that is required for the system (Citron, 2017). For example, because of the artificial intelligence parking the vehicles, vehicles require no extra space between them for a user to access. This information supports the idea that many companies in the United States are researching automated vehicles, and thus smart parking is moving in the direction of fully automated parking garages. The system may succeed in the future as it eliminates the aimless driving and traffic accidents that could occur with human drivers in a parking complex. The system calculates the navigation of the robots, therefore the system is aware of the path that each vehicle will travel. This information can optimize the parking experience and speed of the vehicles. The observed vehicle demographic of Hangzhou citizens displayed no sign of automated vehicles. This is largely dependent upon the fact that at the time of this project's development, companies are still researching automated vehicles.

4.6 Verify and Analyze Feasibility of Discovered Solutions

To justify technical decisions for the proposed system recommendation, the team compared two groups of technological solutions to determine the most feasible system characteristic. The two major comparable groups of decisions consisted of the proposed communication technique and sensing technology. This section summarizes the team's process in completing individual SWOT analyses and reaching conclusions of the most applicable solutions for the overall system recommendation. The team describes the findings from comparing the communication technologies in detail below. The team excluded a comparison of sensing technologies because PShare locks incorporate sensing abilities in a vehicle security device. Appendices M and N displays the respective SWOT analyses of the communication and sensing technologies.

4.6.1 Summary of Communication Technology Analysis

From the information obtained in observations and expert interviews, the team chose to compare RFID, 5G, and Bluetooth as potential communication methods for the final recommendations (see Appendix M). The SWOT analyses tables provides the main findings derived from the team's performed research taking into consideration the findings with respect to consumer and provider needs. When assessing which solutions were most applicable to the final recommendations, the team considered whether the technology was capable of supporting a future system that satisfied the identified consumer and provider needs.

The analysis of RFID technology reached far beyond typical passive tags seen in most commercial parking systems. The team evaluated high frequency passive tags and found that their strengths are long communication ranges and fast scan rates. In systems which require some form of physical hardware for verification, RFID tags hold great potential as each tag is both low cost and well developed within the parking industry. The team's findings showed that while RFID is applicable to certain operations within a parking complex, RFID is slowly becoming outdated as smart technologies move away from physical hardware.

5G was the most well rounded and applicable technology analyzed by the team. It is highly likely 5G will have the potential to be the sole communication method of smart parking solutions. Due to the fact that information on 5G applications is still limited to research and preliminary findings, the team analyzed 5G for its ability to integrate with existing RFID

hardware and transmit large amount of data for extended distances. Considering 5G is currently under development, there are security concerns that are relatable to those of RFID and Bluetooth.

Bluetooth communication modules have installations in nearly all mobile devices. The team valued Bluetooth on its current level of development and recent successes in modern smart parking. While the recommendations for the IoT town are for a future solution, Bluetooth has proved its standard frequency band it is a reliable solution for systems requiring quick connection to mobile devices. On mobile devices, Bluetooth comes with its own inherent disadvantages. One disadvantage is that it's a separate form of communication outside of the RF communication mobile devices currently use. Its lack of ability to connect to a network of other devices, and moderately slow data transmission limits Bluetooth to the application of specific operations within smart parking.

The two technological solutions which were more applicable to a solution that further integrates mobile devices and increases efficiency in the IoT parking complex were 5G and RFID. Backed heavily by the project sponsor and interview subjects, the two technologies also have high potential for future government support in the near future. 5G encompasses multiple facets of an ideal solution, allowing for seamless connection of sensing devices to a mobile platform. While the team recognizes that 5G could potentially connect most of the proposed solution, due to the secure nature of the IoT town, it felt necessary to include a physical form of RFID hardware to increase security. HF RFID tags allow for rapid verification of customers, and can streamline vehicle identification within parking complexes.

4.6.2 Suggested Sensing Solution

During the development of the team's smart parking recommendation, the team's sponsor recommended that the team uses effective technology to address shortcomings and simplify the current smart parking solutions. While the team compared the researched sensing technologies (seen in Appendix N) for their applications within a future parking solution, the final recommendation relies on fewer hardware solutions to create a more efficient system. The interview subjects at PShare discussed that they would install smart locks at the IoT town as a temporary smart parking solution. The team's final recommendation utilizes the existing PShare locks and their integrated vehicle sensing ability to simplify the parking space reservation

technique. A detailed explanation on why the team recommended the PShare locks is in section 5.2.

Chapter 5: Recommendations

This study investigated modern communication technologies and potential system characteristics for a smart parking solution that could address shortcomings of current smart parking systems within Hangzhou, China. The team leveraged consumer and provider needs inferred from observations, surveys, and interviews in order to guide research for an improved smart parking solution. Our research provided insight into the feasibility of different technologies and system characteristics and served as the foundation for the following set of recommendations to serve as general suggestions for a future smart parking system for the Internet of Things (IoT) town in Hangzhou. These recommendations are fit for a characteristic town, and take into account the customer demographic and the constraints specific to the IoT town.

5.1 System Characteristic Recommendations

The below subsections are recommendations formed by the team's research, however they are limited by both time and information available about future technologies. With changes in the direction of the development of smart parking, there is potential for the application of technologies to change. The team has chosen each individual recommendation below for its ability to satisfy previously inferred consumer and provider needs.

5.1.1 PShare Locks

The team recommends that the Smart City Research Center of Zhejiang Province leverages the physical locks that PShare is currently developing for the IoT town for their ability to detect a vehicle's presence and connect wirelessly to mobile devices. As discussed in section 4.5.8, PShare locks have infrared and ultrasonic sensor modules built into the devices. The built in infrared and ultrasonic sensor modules eliminate the need for individual sensor modules installed at each parking space. The team's observation results suggest that current OCR technology deployed at each parking space are ineffective due to the observed error. The team's research results offer successful applications of infrared and ultrasonic sensors in smart parking solutions. The PShare locks ability to incorporate small accurate sensors could satisfy the inferred consumer and provider need of improved availability and vacancy identification. In order to display a parking space availability, the team suggests the installation of an LED light

above the corresponding space. A host computer could use software to label a parking space as occupied and update the parking space's LED light once a vehicle passed over the PShare parking lock. The system could indicate a parking space as occupied through real-time updates of the parking complex's availability on a mobile application. One apparent need unveiled from our research is mobile device integration within future smart parking solutions. While the parking lock's use of Bluetooth will be adequate for a temporary solution, in order for a future solution to improve parking efficiency it will need to incorporate improved communication technologies.

5.1.2 5G Communication

As stated in section 4.5.1 of the research chapter, 5G technology is a large upcoming communication technology for mobile and IoT devices. While the technology is underdeveloped, the technology has high estimated capabilities. Research suggests that 5G technology can connect many devices together with large bandwidth and data transmission speeds. By incorporating 5G communication into the PShare locks instead of Bluetooth, the PShare locks could connect to a cloud platform of the smart parking system. 5G technology will allow the ability to also connect a corresponding LED light for a parking space wirelessly. The ability to connect both the PShare lock and a corresponding LED light wirelessly to a cloud platform will allow for seamless maintenance and real-time information across the complex. This satisfies the need for improved availability and vacancy identification that the project team suggested in section 4.4.1. Due to 5G technology having inherent uncertainties in its current stage of development, the team considered 4G as a possible step forward from Bluetooth technology. The shortcomings of 4G communication identified the technology as infeasible for the team's smart parking application. A future smart parking solution for the IoT town should have the potential to support a complex network of devices. Rather, the team suggests that the IoT town first tests future smart parking solutions with the current Bluetooth modules deployed in PShare's locks to act as a temporary form of communication.

5.1.3 High Frequency RFID Technology

The team recommends RFID technology to be the main form of vehicle identification. RFID technology is widely developed in many applications across the globe for automotive services as the technology's capacity is very high and the overall cost is very low. A parking

complex for the IoT town will have many routine customers that are employees of the businesses within the town. High frequency RFID technology allows for routine customers to have an RFID tag installed in their car for fast identification and verification of a vehicle at the access level of the facility. The increased frequency of the recommended RFID system allows for an increased read range of customer tags. This will allow for a streamlined process of identifying incoming vehicles approaching a typical security gate. The team recommends this technology to streamline the process of only a routine employee entering the IoT town's parking complex. Due to the IoT town being a government facility with confidential projects, the team suggests that a separate identification process screens visitors and non-routine customers. However, the RFID technology could assist in supporting the need for a convenient and economical solution for the IoT town, as it enables routine customers to conveniently enter the facility quickly at a small cost to the complex owners.

5.1.4 Alipay Mini-Apps

The team recommends that the smart parking solution has a direct implementation with Alipay. Results from the observations and interviews represent the overall importance for mobile device integration within Hangzhou. The rapidly growing society has become acquainted to using their mobile devices for many daily services such as public transportation, food delivery services, and bike rentals. The mobile payment methods have become the standard in the area, essentially mitigating the need for cash. For this reason, it is significant to the feasibility of the final proposed system to have integration with mobile devices for as much human-computer interaction as possible. The team proposes that the IoT town's parking complex encompasses the navigation interface and main payment method in the form of an Alipay mini app. Alipay mini-apps are applications within Alipay which link to a user's account for fast payment of services. The Alipay mini apps also have the ability for providers to integrate them directly with a cloud platform, allowing the providers to update information across the system and user devices. The team suggests that a future smart parking system for the IoT town still has a kiosk located within the facility to process cash transactions in the case that a customer does not have access to a mobile device. The LED lights above each parking space also assist with navigating customers without functioning mobile devices to available parking spaces.

5.2 Potential System Application

The project team recommends that the Smart City Research Center of Zhejiang Province implements a future smart parking solution for the IoT town that connects PShare locks, 5G technology, and RFID technology wirelessly. The potential system described in the following section is an example application of the chosen technologies. Due to time constraints of this project, the project team offers the system framework knowing that there may be ambiguities not considered. The team's envisioned system allows for an employee to arrive at the parking complex gate, and seamlessly enter using a high-frequency RFID tag (as shown in Figure 30). When the system identifies that a specific employee's RFID tag has entered the parking complex, it registers their vehicle's presence in an Alipay mini app designed for the parking complex. Naturally, the security gate would be unable to recognize a visitor vehicle, as they would not have a RFID tag present. In this case, a visitor would interact with the present security guard. The team recognizes that the IoT town would have the ability to design a specific protocol for screening visitors.

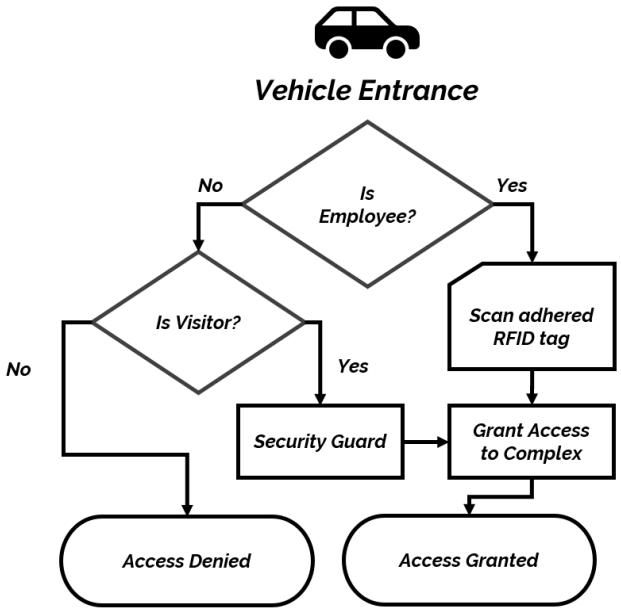

Figure 31: Recommendation for vehicle entrance flowchart

Once the user has entered the parking complex, their mobile device provides a real-time map of the available parking spaces on their current floor. Using 5G communication between the parking locks placed at the front of each parking space, the mobile application marks each spot

on the map using colors to designate a vacant or occupied parking spot. In addition to the mobile device interface, the team believes the additional aid of using network-connected indicator lights above each spot is necessary. LED lights above each parking space would display the corresponding parking spot's availability through a wireless 5G connection. The employee then drives their vehicle to the available spot of their choice and enters the spot, driving over an already lowered gate. The team suggests the IoT town to designate specific parking spaces for visitors and priority employees. Figure 32 displays the user process of navigating to an available parking space.

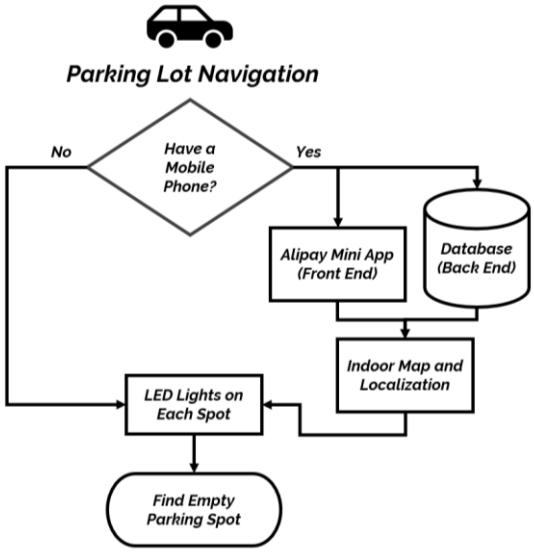

Figure 32: Recommendation for parking complex navigation

As described in section 4.5.8, the current PShare parking locks can register when a vehicle passes over the parking lock which prompts the lock to rise once the car has entered. The lock detects when a vehicle enters the parking space with an infrared sensor placed on the lock itself (Shown in Figure 33). The employee's phone begins to calculate their parking fare and marks the spot as occupied in a cloud platform and mobile application. When the user chooses to leave the parking complex, they simply pay for their parking via typical Alipay mobile payment or at a kiosk in the complex, which lowers the PShare gate and updates the parking spot as vacant in the system.

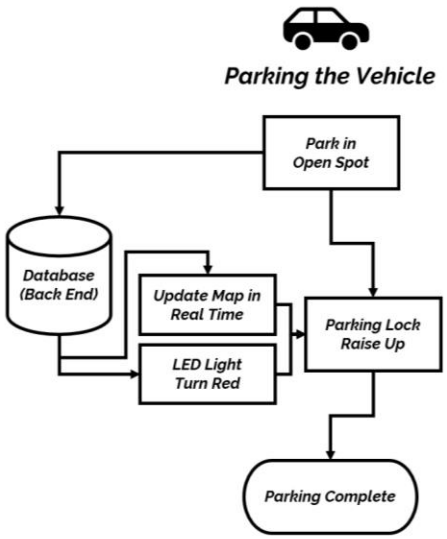

Figure 33: Recommendation for vehicle parking

In instances where a user either forgets their mobile device or is unable to access the mobile application, they will still be able to enter the parking complex using their RFID tag and pay for an available spot. The team envisions that HF RFID tags adhered to the windshield of the vehicle would allow them access through the security gate. Once in the parking complex, the employee will be able to similarly find and enter a parking spot. The system will still mark the spot as occupied once the gate is upright. The team believes that future smart parking solutions cannot adequately justify completely removing management personnel, therefore if a consumer encounters an issue within the facility a management person will be at the front booth. Also, the mobile application will have a support contact to reach an administrator of the parking complex. The single management person on site in a booth near the security gate can oversee manual payments and screen incoming complex visitors. Figure 34 explains the process of how users can complete transactions to exit the parking complex.

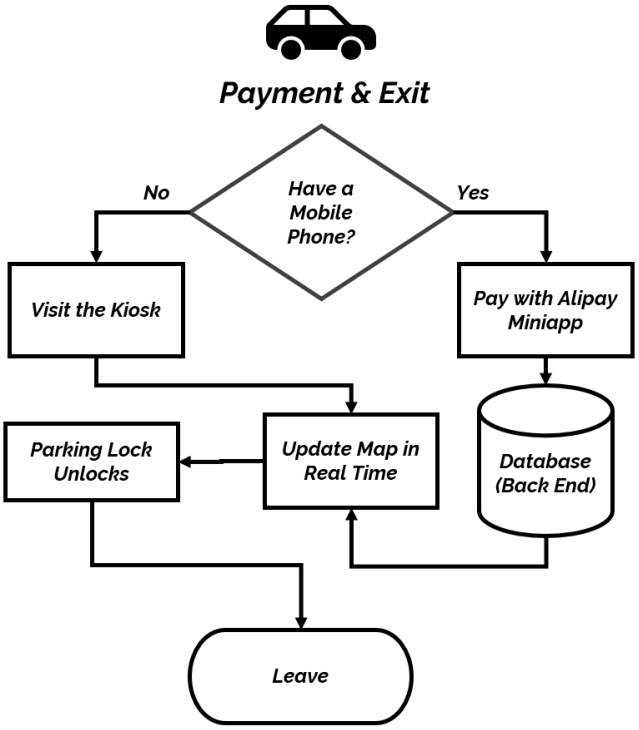

Figure 34: Recommendation for payment and exit from the parking complex

The proposed smart parking system has a variety of potential features used for parking space reservation. By allocating specific spots to "visitor spaces", the businesses within the IoT town could reserve spots for specific time slots to accommodate their business visitors. The spaces set aside for visitors could have their gates in the upright position to avoid employees taking the visitor reserved spaces. The team suggests a visitor screening process in which an employer provides a verification code to their guest prior to their visit. The verification code could allow them to use the Alipay mini-app to receive access to a specific parking lock designated to them. In instances where all of the allotted visitor spots are not reserved, the gates can be kept lowered and appear as vacant on the map for employees to utilize. Lastly, a similar technique can reserve spots for customers of priority within the parking garage. If a specific employee required a daily reserved parking space, the project team believes that using a verification code to allow only their Alipay account to access a spot would be a proper way of designating spots for priority employees.

5.3 Future Direction & Research Limitations

This study suggests that a smart parking system for the IoT town in Hangzhou, China should leverage the current parking locks PShare is developing as well as implement 5G and RFID technologies. This report encompasses the team's recommendations based on the collected data and research from a seven-week period. Given the time constraints of the project, in order to more accurately qualify the technologies best-fit for the IoT town's smart parking solution, further research is necessary. The team researched and investigated laws pertaining to this solution in section 2.8.1, however, the project team did not have the time necessary to cross-reference the solution logistics with all applicable government regulations. Research also suggested to the team that there are many research centers across the globe currently investigating automated parking solutions. These automated parking solutions consist of robotic parking systems and self-parking vehicles. However, these automated parking solutions were out of the scope of this project due to them being in very early stages of research, with many unanswered questions.

One important factor to consider in regards to the further development of this study is that the Chinese government promotes specific types of technology regularly. When this occurs, corporations and research centers adopt the technology and thus the technology grows rapidly within the country. This is important to consider as future technologies promoted by the government may develop at a rapid pace and have a significant role in future smart parking solutions within China. The team's discussions with the interview subjects brought forth the idea of electronic license plates tied to a vehicle to act as a universal and standardized form of vehicle identification. At the time of this report, China's government was promoting the electronic license plates and therefore the team expects that the technology will develop at a rapid place amongst the industry. While a few statements from industry experts supported this expectation, the electronic license plates were out of scope from the final solution as many of their capabilities were unknown by the interview subjects. The team suggests that researchers should conduct future studies around the electronic license plates to verify their feasibility for smart parking applications in China.

The interview and corresponding site visit to Alibaba depicted biometric data as a future payment verification method. The employee of Alibaba stated that in the future he believes China will diminish the widespread use of mobile payment and use biometric data as a form of

payment. There is indications of current research on biometric data as a potential future payment method in China. However, the project team was unable to find sufficient information to support the feasibility and social implications of such a recommendation.

5.4 Conclusion

The goal of this project was to offer a recommended application of suggested technologies for a future smart parking solution for the Internet of Things town. Through observations of the current systems and consultations with relevant stakeholders, the team was able to propose a solution which suggested further integration of improved communication technologies and non-contact mobile payment methods. The combined use of high-frequency passive RFID technology, 5G technology, and improved PShare parking locks could guide research and development of future smart parking solutions for characteristic towns in Hangzhou.

Bibliography

Adler, L. (2016, February 18). How Smart City Barcelona Brought the Internet of Things to Life. Retrieved September 6, 2018, from https://datasmart.ash.harvard.edu/news/article/how-smart-city-barcelona-brought-the-internet-of-things-to-life-789

Alipay. (n.d.). 介绍 [Mini App Introduction]. Retrieved December 2, 2018, from https://docs.alipay.com/mini/introduce

Apple. (2014, June 2). Getting Started with iBeacon. Retrieved December 2, 2018, from https://developer.apple.com/ibeacon/Getting-Started-with-iBeacon.pdf

Apple. (2017, August 05). About iBeacon on your iPhone, iPad, and iPod touch. Retrieved December 1, 2018, from https://support.apple.com/en-gb/HT202880

Bai, Y. B., Wu, S., Wu, H., & Zhang, K. (2012). Overview of RFID-based Indoor Positioning Technology. Retrieved September 13, 2018. doi:10.1.1.684.9283

北京青年报[Beijing Qingnian News] (2016, January 12). 微信公众号将推"应用号" 最快2016年上线 [WeChat is Announcing “Application Accounts”]. Retrieved December 2, 2018, from http://www.xinhuanet.com//info/2016-01/12/c_135000569.htm

Bluegiga. (2015, June 8). Bluetooth Pairing Mechanism (Legacy Pairing and Secure Simple Pairing (SSP)). Retrieved December 1, 2018, from https://www.silabs.com/community/wireless/bluetooth/knowledge-base.entry.html/2015/08/06/bluetooth_pairingma-Fe61

Blystone, D. (2018, August 30). The Story of Uber. Retrieved September 13, 2018, from https://www.investopedia.com/articles/personal-finance/111015/story-uber.asp

Bonsor, K., & Fenlon, W. (2007, November 05). How RFID Works. Retrieved September 13, 2018, from https://electronics.howstuffworks.com/gadgets/high-tech-gadgets/rfid3.htm

Boularess, O., Rmili, H., Aguili, T., & Tedjini, S. (n.d.). A Block Diagram of a Typical RFID System [Digital image]. Retrieved September 14, 2015, from https://www.researchgate.net/figure/A-block-diagram-of-a-typical-RFID-system_fig1_287390756

Brown, F., & Fox, B. (2013, August 03). RFID Hacking. Lecture Presented at DefCon in Nevada, Las Vegas. Retrieved September 9, 2018, from

https://www.defcon.org/images/defcon-21/dc-21-presentations/Brown/DEFCON-21-Brown-RFID-Hacking-Updated.pdf

Burnett, R. (2018, July 26). Ultrasonic vs Infrared (IR) Sensors - Which is better? Retrieved December 2, 2018 from https://www.maxbotix.com/articles/ultrasonic-or-infrared-sensors.htm?_vsrefdom=adwords&gclid=Cj0KCQiAoo7gBRDuARIsANeJKUblDI3UNDHuU47egUDfQbBBGzcwTYhBuQS5e98mgyr6ecv-4uLC2KgaAlsyEALw_wcB

Burt, C. (2018, May 30). Etron Supplying Visual Sensor Modules to Self-service Alibaba Store. Retrieved December 2, 2018, from https://www.biometricupdate.com/201805/etron-supplying-visual-sensor-modules-to-self-service-alibaba-store

Burt, C. (2018, July 13). Alibaba and Marriott Partner for Trial of Facial Recognition Hotel Check-in. Retrieved December 2, 2018, from https://www.biometricupdate.com/201807/alibaba-and-marriott-partner-for-trial-of-facial-recognition-hotel-check-in

Cameron, J. (2015). Some things you might not know about E-ZPass [Photography]. Retrieved from https://live.han.network/the-secrets-of-e-zpass/

Cavada, M., Hunt, D. V., & Rogers, C. D. (2014, November 1). Smart Cities: Contradicting Definitions and Unclear Measures. Retrieved September 8, 2018, from https://sciforum.net/manuscripts/2454/manuscript.pdf

Chaisatien, W. (2016, August 12). End of the Car Park Cruise – Buildings and Facilities Get Smart with IoT at IDF. Retrieved November 29, 2018, from https://www.ericsson.com/thinkingahead/the-networked-society-blog/2016/08/12/end-of-the-car-park-cruise-buildings-and-facilities-get-smart-with-iot-at-idf/#more-9622

Chaturvedi, A. (2018, March 13). Did You Know Which are the Top 3 Smart Cities in the World? Retrieved September 22, 2018, from https://www.geospatialworld.net/blogs/top-3-smart-cities-world/

Chatzky, J. (2018, May 9). Biometrics Are Here: The Crazy Ways You're Going to be Paying in the Future. Retrieved December 2, 2018, from https://www.nbcnews.com/better/business/biometrics-are-here-crazy-ways-you-re-going-be-paying-ncna872336

Cheng. (2018, January 03).支付宝发布2017年全民账单 用户移动支付占比82% [Alipay announced annual report. Mobile payment takes 82% of payment market]. Retrieved

December 2, 2018, from http://media.people.com.cn/n1/2018/0103/c40606-29741442.html

Cheng, I. (2015, March 18). Legislative Council of the Hong Kong Special Administrative Region - What is a "Smart City"? Retrieved September 8, 2018, from https://www.legco.gov.hk/research-publications/english/essentials-1415ise08-what-is-a-smart-city.htm

Chengxi, Y. (2018, January 25). Hangzhou: A Chinese Smart City. Retrieved September 14, 2018, from https://news.cgtn.com/news/7a556a4e7a677a6333566d54/share_p.html

Chenlei, Z. (2017, April 17). App Wants to Solve Shanghai's Notorious Parking Problem. Retrieved September 15, 2018, from https://news.cgtn.com/news/3d6b444d78557a4d/share_p.html

央视财经 [China Central Television Finance]. (2017, April 16). 上海："共享停车"来了，错峰停车解决没车位问题 [Shanghai “Shared Parking” in Action. Resolves the Problem of Having Not Enough Parking Spots]. Retrieved December 2, 2018, from https://www.sohu.com/a/134382747_114960

Citron, R. (2017, June 29). The Future Of Smart Parking Is Integration With Automated Technology. Retrieved December 2, 2018, from https://www.forbes.com/sites/pikeresearch/2017/01/26/smart-parking/#7e07820262f6

Clare. (2016, March 29). Ultrasonic Sensors Market By Types, By Application, By Industry - Global Industry Analysis, Trend, Size, Share and Forecast 2015 - 2023. Retrieved November 30, 2018, from https://www.prnewswire.com/news-releases/ultrasonic-sensors-market-by-types-by-application-by-industry---global-industry-analysis-trend-size-share-and-forecast-2015---2023-300243058.html

CSDN. (2018, September 1). 这款支付宝停车小程序 让停车场一年能节省100万成本[This Alipay Parking Mini App, Cuts the Budget of Parking Lot by 10 Million Yuan Per Year]. Retrieved November 30, 2018, from https://www.csdn.net/article/a/2018-01-10/15939741

Currie, Cameron, Dall’Osro, Rebecca, Khun, Monineath, & Li, Max. (2016, March 04). Assessing Smart City Initiatives in Kowloon East. Retrieved September 5, 2018, from

https://web.wpi.edu/Pubs/E-project/Available/E-project-031516-111045/unrestricted/UDP_Team_Final_Report.pdf

Downes, L. (2015, October 26). What is 5G and Why Should Lawmakers Care? Retrieved November 27, 2018, from https://www.washingtonpost.com/news/innovations/wp/2015/10/26/what-is-5g-and-why-should-lawmakers-care/?noredirect=on&utm_term=.25e5d25e1b0b

Fabian, B., Gunther, O., & Ziekow, H. (2010). RFID and the Internet of Things: Technology, Applications, and Security Challenges. *ResearchGate, 4*. doi:10.1561/0200000020

Frost, & Sullivan (2014, November 26). Global Smart Cities Market to Reach US$1.56 Trillion by 2020 Finds Frost & Sullivan. Retrieved September 13, 2018, from https://www.newswiretoday.com/news/148711/Global-Smart-Cities-Market-to-Reach-US1.56-Trillion-by-2020-Finds-Frost-and-Sullivan/

Gao. (2018, January 18). **我国汽**车保有量达2.17亿辆 **杭州**约244**万**辆 [China's Number of Vehicle Possession has Reached 217 Million and Hangzhou has 2.44 Million] - **杭州新**闻中心[Hangzhou News]. Retrieved September 13, 2018, from http://hznews.hangzhou.com.cn/jingji/content/2018-01/18/content_6776409.htm

Glasmeier, A., & Christopherson, S. (2015). Thinking About Smart Cities. *Cambridge Journal of Regions, Economy and Society, 8 (1).*

Goldman, D. (2018, January 29). What is 5G? Retrieved November 28, 2018, from https://money.cnn.com/2018/01/29/technology/what-is-5g/index.html

Goode, A. (2018, July 11). Biometric Identification or Biometric Authentication? Retrieved December 2, 2018, from https://www.veridiumid.com/blog/biometric-identification-and-biometric-authentication/

Griffinger, R., & Haindl, G. (2007). Smart Cities Ranking: An Effective Instrument for the Positioning of Cities? Retrieved September 8, 2018, from https://core.ac.uk/download/pdf/41793309.pdf

GSMA. (n.d.). Narrowband – Internet of Things (NB-IoT). Retrieved December 2, 2018, from https://www.gsma.com/iot/narrow-band-internet-of-things-nb-iot/

Hangzhou City Government. (2018, August 12). **今年杭州所有道路停**车泊位 **基本**实现无感支付 [Major Parking Lots in Hangzhou Have Non-contact Payment Methods Implemented].

Retrieved August 29, 2018, from http://www.hangzhou.gov.cn/art/2018/8/12/art_812262_20258740.html

Hangzhou City Government. (2018, August 13). 今年全市已新建31081个停车泊位 [31,081 New Parking Spots Have Been Newly Built Across the City]. Retrieved September 4, 2018, from http://www.hangzhou.gov.cn/art/2018/8/13/art_812262_20271263.html

Hangzhou Municipal Public Security Bureau. (2018, July 9). 2018年1-6月交通事故情况 [Traffic Incidents of January~June, 2018]. Retrieved September 17, 2018, from http://www.hangzhou.gov.cn/art/2018/9/3/art_1256302_20912025.html

Hao, K., & Zhou, Y. (2018, March 01). China is Beating Back Traffic in its Most Congested Cities. Retrieved September 22, 2018, from https://qz.com/1217257/china-is-beating-back-traffic-in-its-most-congested-cities/

Hiphen. (n.d.). Parking guidance system [Picture]. Retrieved from http://hiphensolutions.com/parking-guidance-parking/

Ho, C. K. (2017, December 12). Alibaba's Next Moon Shot is to Make Cities Adapt to their Human Inhabitants. Retrieved September 22, 2018, from https://www.scmp.com/tech/innovation/article/2123856/alibabas-tech-seer-sees-making-cities-adapt-their-inhabitants-next

Hsu, J. W. (2018, September 20). Alibaba Cloud Launched 'ET City Brain 2.0' in Hangzhou. Retrieved September 22, 2018, from https://www.alizila.com/alibaba-cloud-launched-city-brain-2-0-hangzhou/

Huawei. (2017, June 16). Huawei Partnered with Shanghai Unicom to Pilot 4.5G NB-IoT. Retrieved December 2, 2018, from http://carrier.huawei.com/en/success-stories/products-and-solutions/chinaunicom_nbiot_smartparking

Huibiao Technology. (n.d.). 电子车牌 [Electronic License Plate]. Retrieved December 1, 2018, from http://www.cqrfid.cn/a/plate/

Ibeaconinsider. (2014, June 13). What is iBeacon? A Guide to iBeacons. Retrieved December 1, 2018, from http://www.ibeacon.com/what-is-ibeacon-a-guide-to-beacons/

Idris, M. Y., Leng, Y. Y., Tamil, E. M., Noor, N. M., & Razak, Z. (2009). Car Park System: A Review of Smart Parking System and Its Technology. *Information Technology Journal 8*, 101-113. doi:10.3923/itj.2009.101.113

IEC. (2018). Why Cities Need to Become Smart Now. Retrieved September 17, 2018, from http://www.iec.ch/smartcities/connecting_things.htm

Javaid, S., Sufian, A., Pervaiz, S., & Tanveer, M. (2018, March 26). *Smart Traffic Management System Using Internet of Things.* Paper presented at 2018 20th International Conference on Advanced Communication Technology (ICACT), Chuncheon, South Korea. doi: 10.23919/ICACT.2018.8323770

JParking. (n.d.). Parking Complex Solution. Retrieved November 30, 2018, from http://www.jparking.cn/solution_complex.aspx?FId=n25:25:25

Kianpisheh, A., Mustaffa, N., Limtrairut, P., & Keikhosrokiani, P. (2012, July). Smart Parking System (SPS) Architecture Using Ultrasonic Detector. Retrieved November 29, 2018, from https://www.researchgate.net/publication/230701092_Smart_Parking_System_SPS_Architecture_Using_Ultrasonic_Detector

Lashinsky, A. (2017, May 18). Riding Shotgun With Uber CEO Travis Kalanick. Retrieved October 6, 2018, from http://fortune.com/2017/05/18/uber-travis-kalanick-wild-ride/

Lin, C. J. (2018, July 11). Five Chinese Smart Cities Leading the Way. Retrieved September 14, 2018, from https://govinsider.asia/security/five-chinese-smart-cities-leading-way/

Lockner, J. (2015, August 17). Big Data. Retrieved September 13, 2018, from http://sandhill.com/article/is-data-decentralization-the-new-trend/

Ma. (2016, March 2). What Are Characteristic Towns in Zhejiang? Retrieved November 29, 2018, from http://www.china.org.cn/china/NPC_CPPCC_2016/2016-03/02/content_37918420.htm

Madhani, A. (2017, June 06). Chicago Cabbies Say Industry is Teetering Toward Collapse. Retrieved September 14, 2018, from https://www.usatoday.com/story/news/2017/06/05/chicago-cabbies-say-industry-teetering-toward-collapse/102524634/

McQuarrie, L. (2018, April 27). Futuristic Cashierless Stores: Futuremart. Retrieved December 2, 2018, from https://www.trendhunter.com/trends/futuremart

MSR-Traffic. (n.d.). Parking Guidance System Enhances the Attractiveness of Shopping Center “Stadtgalerie Passau”. Retrieved December 2, 2018, from https://www.msr-traffic.de/en/projects/stadtgalerie.html

Ministry of Industry and Information Technology of the PRC. (2017, July 13). S无线电频率使用许可管理办法 [Permission of Usage of Radio Frequency]. Retrieved September 4, 2018, from http://www.miit.gov.cn/n1146295/n1146557/n1146624/c5727360/content.html

National People's Congress of the PRC. (2016, December 13). 中华人民共和国道路交通安全法 [Laws of Road Traffic Safety of the PRC]. Retrieved September 5, 2018, from http://www.npc.gov.cn/npc/zfjc/zfjcelys/2016-12/13/content_2003512.htm

Ng, J. W. P., Azarmi, N., Leida, M., Saffre, F., Afzal, A., & Yoo, P. D. (2010). *The Intelligent Campus (iCampus): End-to-end Learning Lifecycle of a Knowledge Ecosystem.* Paper presented at Sixth International Conference on Intelligent Environments, 332-337, Kuala Lumpur, Malaysia. doi:10.1109/IE.2010.68

Northcott, H., Landergan, M., Abualhaija, R., Dodani, P., & Hartnett, V. (2017). Assessing Smart Mobility in Madinat AI Irfane. Assessing Smart Mobility In Madinat AI Irfane. Retrieved August 29, 2018, from http://web.cs.wpi.edu/~rek/

Nwave. (2018). Smart Parking Technology by Nwave. Retrieved December 2, 2018, from https://www.nwave.io/parking-technology/

Pala, Z., & Inanc, N. (2007). Smart Parking Applications Using RFID Technology. Retrieved September 15, 2018. doi: 10.1109/RFIDEURASIA.2007.4368108

Parkifi. (2018). Let's Talk Hardware – ParkiFi and the Sensor Revolution. Retrieved December 2, 2018, from https://www.parkifi.com/blog/lets-talk-hardware

Plautz, J. (2018, July 11). London, Singapore Lead Ranking of World's Smart Cities. Retrieved September 15, 2018, from https://www.smartcitiesdive.com/news/london-singapore-lead-ranking-worlds-smart-cities-Eden-Strategy-Institute/527482/

PShare. (n.d.). Autosensing Parking Lock. Retrieved December 6, 2018, from http://www.pshare.com/product_en.html?id=cp

Rawlins, A. (2015, June 24). You'll never have to search for a parking spot again. Retrieved December 1, 2018, from https://money.cnn.com/2015/06/24/technology/parking-startups-parkifi/index.html

Roberti, M. (2014, July 14). Which RFID System is Right for Managing Parking Areas? Retrieved August 6, 2018, from https://www.rfidjournal.com/blogs/experts/entry?11098

Ross, V. (2011, February 17). Smart Parking Systems Steer Drivers to Open Spaces. Retrieved December 2, 2018, from https://www.popularmechanics.com/technology/gadgets/a6528/smart-parking-systems-steer-drivers-to-open-spaces/

Rouse, M. (2006, August). Biometric Payment. Retrieved December 2, 2018, from https://searchsecurity.techtarget.com/definition/biometric-payment

Rouse, M. (2014, December). Biometric Authentication. Retrieved December 2, 2018, from https://searchsecurity.techtarget.com/definition/biometric-authentication

Rouse, M., & Finnell, K. (2015, April). What is Millimeter Wave (MM wave)? Retrieved November 29, 2018, from https://searchtelecom.techtarget.com/definition/millimeter-wave-MM-wave

赛文交通网 [Seven Traffic Net]. (2017, June 22). **上海智能停**车：已实现2300**个公共停**车场库信息联网 [Shanghai Smart Parking: 2300 Public Parking Lots Have Connected Database to the Network]. Retrieved December 2, 2018, from https://www.sohu.com/a/150979463_389742

Shanghai Government. (2012, September 20). **上海市停**车场（库）管理办法（沪府令85**号**） [Shanghai City Parking Lot Regulation (Shanghai Government Regulation #85)]. Retrieved December 2, 2018, from http://www.shanghai.gov.cn/nw2/nw2314/nw2319/nw2407/nw29400/u26aw33321.html

Shanghai Public Traffic Card Co. Ltd. (2015, November 08). Shanghai Parking App [**上海停**车]. Retrieved December 2, 2018, from https://itunes.apple.com/cn/app/shang-hai-ting-che/id1053818557?mt=8

Sheridan, V., Tsegaye, B., & Walter-Echols, M. (2005, March 4). ZigBee-enabled RFID Reader Network (Undergraduate Major Qualifying Project). Retrieved August 29, 2018, from https://web.wpi.edu/Pubs/E-project/Available/E-project-041706-150556/unrestricted/ZigBee_Enabled_RFID_Reader_Network_Report.pdf

Sina Tech. (2018, January 04). Alipay Unveils Annual Report for Wallet-Free Chinese Users. Retrieved September 6, 2018, from https://pandaily.com/alipay-unveils-bill-payment-for-wallet-free-chinese-users/

Smart London Board. (2013). Smart London plan. Retrieved September 5, 2018, from http://www.london.gov.uk/sites/default/files/smart_london_plan.pdf

Smartcity. (2017, October 27). What Makes London One of the Smartest Cities in the World. Retrieved September 5, 2018, from https://www.smartcity.press/londons-smart-city-initiatives/

SmartParking. (2014, October 29). Westminster City Council Goes Live with Smart Parking's SmartPark Real-time Bay Sensor Parking Solution. Retrieved December 1, 2018, from https://www.smartparking.com/keep-up-to-date/press-releases/westminster-city-council-goes-live-with-smart-parking-s-smartpark-real-time-bay-sensor-parking-solution

智慧交通 [Smart Traffic]. (2017, November 15). **朱昊**: **上海智慧停**车发展状况和趋势探讨 [Zhu Hao: Shanghai Smart Parking State of Developement and Discussion of Trends]. Retrieved December 2, 2018, from https://www.sohu.com/a/204602702_649849

Sohu. (2017, March 31). **你真的知道特色小**镇是什么吗? [Do you really know what a characteristic town is?]. Retrieved September 5, 2018, from http://www.sohu.com/a/131393849_210348

State Radio Regulation of China. (2016, November 28). **中**华人民共和国无线电管理条例 [Radio Frequency Usage Regulations of People's Republic of China]. Retrieved September 4, 2018, from http://www.srrc.org.cn/article18726.aspx

Survey Department of Hangzhou. (2017, March 8). 2017**年杭州市国民**经济和社会发展统计公报 [Hangzhou Citizen Economy and Social Development Announcement of 2017]. Retrieved September 17, 2018, from http://www.hangzhou.gov.cn/art/2018/5/21/art_1256301_18193656.html

Tianzhi Intellective Technology Co. Ltd. (2018, January 2). 车牌识别系统 [Vehicle Identification System]. Retrieved November 1, 2018, from http://www.tianzhiit.com/project/gcwj/xt_clcrzn.html

Tsiropoulou, E. E., Baras, J. S., Papavassiliou, S., & Sinha, S. (2017). RFID-Based Smart Parking Management System, *Cyber-Physical Systems*, 3:1-4, 22-41. doi:10.1080/23335777.2017.1358765

Vesco, A., & Ferrero, F. (2015). Handbook of Research on Social, Economic, and Environmental Sustainability in the Development of Smart Cities. Retrieved September 17, 2018, from https://app.knovel.com/hotlink/toc/id:kpHRSEESD3/handbook-research-social/handbook-research-social

Windmill Software Ltd. (n.d.). Vehicle Sensing: Ten Technologies to Measure Traffic. Retrieved December 4, 2018, from http://www.windmill.co.uk/vehicle-sensing.html

Xi. (2017, July 01). 2017年Q1第三方支付市场份额数据：支付宝占比54%夺魁 [Mobile Payment Market Status of 2017 Q1: Alipay Took the First Place with a Percentage of 54%]. Retrieved December 1, 2018, from https://www.ithome.com/html/it/315005.htm

Xianzhi Qiche. (2018, October 08). 电子车牌到底要不要强制安装，交警给出解释，这几点车主不用担心 [Are Electronic License Plate Required for Vehicles? Traffic Police Explains.] Retrieved December 1, 2018, from http://www.sohu.com/a/258225494_100225426

Xiaoxiao Morning News. (2018, January 02). 今年起将全面推广电子车牌 [Electronic License Plate will be Promoted Starting 2018]. Retrieved December 1, 2018, from http://money.163.com/18/0102/03/D7461E1D002580S6.html

Xuequan, M. (Ed.). (2018, January 25). China Focus: Smartphone Apps Help Ease Parking Headache in Beijing. Retrieved September 15, 2018, from http://www.xinhuanet.com/english/2018-01/25/c_136924972.htm

Yang, S. S., & Huang, L. X. (2017). Research on Planning and Management of Urban Parking Lot - Taking Hangzhou as an Example. *Current Urban Studies*, 5, 379-386. doi:10.4236/cus.2017.54021

Zhongfu Research Center. (2018, June 26). 电子车牌6项国标实施在即 千亿级市场即将打开 [6 National Standard of Electronic License Plates are Immient]. Retrieved January 2, 2018, from http://news.rfidworld.com.cn/2018_06/bad774d596e70d79.html

Zhu, H., & Yu, F. (2015, July 8). A Vehicle Parking Detection Method Based on Correlation of Magnetic Signals. Retrieved December 2, 2018. doi: 10.1155/2015/361242

Appendix A: Informed Consent Form for Interview (English Version)

INFORMED CONSENT STATEMENT

Greetings, we are a group of students from Worcester Polytechnic Institute (WPI) located in the United States. We are surveying parking complex customers/users and interviewing Research & Graduate students and Industry Experts in order to understand the challenges and perspectives of the current parking systems in Hangzhou. Our hope is to create an efficient smart parking system solution that could be developed in the Internet of Things (IoT) characteristic town located in Hangzhou.

Your participation in this survey/interview is completely voluntary, therefore you can leave at any time. The subject will remain anonymous unless stated otherwise. If stated otherwise, our team has consent from the participant to use their name in the project, if the team chooses to.

This is a collaborative project between the Smart City Research Center of Zhejiang Province and Worcester Polytechnic Institute. Participation in this interview is greatly appreciated and a final copy of the paper will be made available to all interested participants.

The following selections are optional, but your participation is greatly appreciated and may help our project significantly. Please select the options that you are comfortable with.

[ ] I authorize the team to record the interview's audio for strictly analysis.

[ ] I authorize the team to use my name in their data report.

SIGNATURE:_____

DATE:_____

Appendix B: Informed Consent Form for Interview (Chinese Version)

知情同意声明

您好，我们是来自美国伍斯特理工学院（WPI）的学生。我们想通过采访停车场相关工作人员，科技公司等对象的方式了解调查对象对其所负责的停车系统的看法及当前杭州停车系统所面临的挑战。我们希望能够针对杭州的物联网特色小镇设计出合理的停车系统。

您是自愿选择参与本调查/研究的。因此，您可以随时离开并放弃参与研究。除非明确表明，您的名字等信息不会被公开。明确表明需要公开个人信息的情况下，我们将会向您先征得同意。

本研究项目是伍斯特理工学院与浙江省杭电智慧都市研究中心的合作项目。我们由衷地感谢您能够参与本项目的调查内容。若您有兴趣，我们可以在项目结束后向您提供我们撰写的关于该项目的学术论文。

以下部分的选项为选择性参与。参与这些内容将会更好地帮助我们的团队完成项目。我们的团队对您愿意参与以下的内容表示由衷的感谢。请选择您愿意参与的选项。

[ ] 我允许项目团队对本次采访进行录音用于分析。

[ ] 我允许项目团队在项目报告中使用我的姓名。

参与者签名:

_____

日期:

_____

Appendix C: Parking Complex Customers/Users Survey (English Version)

Planning Details:

The intended purpose of these surveys is to gather customer and survey data in parking complexes. The team will ask to be accompanied by at least one Chinese buddy to be able to clearly communicate if any situation arises. The Chinese buddy will use the "Introductory Statement Outline" as reference to grab the attention of the potential survey takers. The statement is written in English below, but will be translated and spoken in Chinese while administering surveys. A printed quick survey will be handed out to customers or users of the parking complex.

Introductory Statement Outline for Chinese Buddy: Greetings, we are a group of students from Worcester Polytechnic Institute (WPI) located in the United States. We are surveying parking complex customers/users in order to understand the challenges and perspectives of the current parking systems in Hangzhou. Our hope is to create an efficient smart parking system solution that could be developed in the Internet of Things (IoT) characteristic town located in Hangzhou.

Printed Survey:

Confidentiality Statement: Your participation in this survey is completely voluntary, therefore you can leave at any time. The subject will remain anonymous.

Complex Address:
Time of Day:

1. What type of motor vehicle do you own?
    - Car [ ]
    - Motorcycle [ ]
    - Moped [ ]
    - Other [ ]
2. Where do you usually park it?
    - Commercial Parking Lots [ ]
    - Private Parking Lots [ ]
    - Shared Parking Lots [ ]
    - Streets [ ]
3. Is there a particular reason that you park it there?

_____

_____

4. Do you frequently use this parking complex?
    - Yes ( )
    - No ( )
5. Do you think the technology used in the parking lot is sufficient?

- Yes ( )
- No ( )

6. Have you experienced any issues when parking in this complex? Briefly explain the issues.

_____

_____

_____

7. Please rate how difficult it is to find an empty parking space in the parking lot?

0 1 2 3 4 5 6 7 8 9 10

Very Easy Moderate Very Difficult

8. Is it easy to find your car?
   - Yes ( )
   - No ( )
9. Please rate the safety of the following:
   - Vehicle Safety

     0 1 2 3 4 5 6 7 8 9 10

     Not Safe Safe
   - Personal Safety

     0 1 2 3 4 5 6 7 8 9 10

     Not Safe Safe

Appendix D: Parking Complex Customers/Users Survey (Chinese Version)

Planning Details:

The intended purpose of these surveys is to gather customer and survey data in parking complexes. The team will ask to be accompanied by at least one Chinese buddy to be able to clearly communicate if any situation arises. The Chinese buddy will use the "Introductory Statement Outline" as reference to grab the attention of the potential survey takers. The statement is written in English below, but will be translated and spoken in Chinese while administering surveys. A printed quick survey will be handed out to customers or users of the parking complex.

Introductory Statement Outline for Chinese Buddy: Greetings, we are a group of students from Worcester Polytechnic Institute (WPI) located in the United States. We are surveying parking complex customers/users in order to understand the challenges and perspectives of the current parking systems in Hangzhou. Our hope is to create an efficient smart parking system solution that could be developed in the Internet of Things (IoT) characteristic town located in Hangzhou.

Printed Survey:

保密声明：您是自愿选择参与本调查/研究的。因此，您可以随时离开并放弃参与研究。您的名字等信息不会被公开。

Complex Address:
Time of Day:

1. 您拥有哪种类型的车辆？（汽车，摩托车，其他）
    - 汽车 [ ]
    - 摩托车 [ ]
    - 电瓶车 [ ]
    - 其他 [ ]
2. 您通常的停车地点是？
    - 商用停车场 [ ]
    - 私家停车场 [ ]
    - 共享停车场 [ ]
    - 街边 [ ]
3. 您为何将其停在该处？

4. 您工作/生活的地方离该处近吗？

- 是 ( )
- 否 ( )

5. 停车场所提供的科技是否满足您的需求？

- 是 ( )
- 否 ( )

6. 您在停车时是否有遇到任何由停车场本身缺陷造成的的问题？请简单阐述您遇到的问题。

7. 您在停车场中能否轻易找到空闲的停车位？

0 1 2 3 4 5 6 7 8 9 10

非常容易 适中 非常困难

8. 取车时，您能否轻易找到自己所停的车？

- 是 ( )
- 否 ( )

9. 请评价停车场中以下两项的安全指数（0-非常不安全 10-非常安全）

- 车辆安全

0 1 2 3 4 5 6 7 8 9 10

不安全 安全

- 人身安全

0 1 2 3 4 5 6 7 8 9 10

不安全 安全

Appendix E: Industry Experts Interview (English Version)

Planning Details:

The intended purpose of these interview questions is to guide the team to have a semi-structured interview with Industry Experts. The team will ask to be accompanied by the sponsor, a Chinese buddy or a Chinese translator. A printed copy of the interview questions and the informed consent form will be provided in English and Chinese to the interview subjects for reference. The informed consent form contains the introductory statement and confidentiality statement for the interviewee to read. A phone will be used for recording purposes if the interviewee agrees to be recorded.

Preliminary Information:

Interviewers:
Interviewee:
Interview Date:
Location:
Audio Recorded by:

Translated by:
Transcribed by:
Transcription Date:

Permission to include interviewee's name in report:
Permission to use an audio and/or video recording of this interview:

Interview Questions:

1. What is your role in the development of smart parking?
2. What are your companies' goals for developing smart parking in Hangzhou?
3. What forms of future technology do you expect to see implemented in smart parking?
4. Please order the following factors in order of importance for smart parking in China. (1 being the most important)
    - Parking Efficiency [ ]
    - Convenience [ ]
    - Price [ ]
    - Safety [ ]
    - Availability [ ]
5. What type of data do you think is important in a smart parking system?
6. What suggestions do you have for our team's project?

Appendix F: Industry Experts Interview (Chinese Version)

Planning Details:

The intended purpose of these interview questions is to guide the team to have a semi-structured interview with Industry Experts. The team will ask to be accompanied by the sponsor, a Chinese buddy or a Chinese translator. A printed copy of the interview questions and the informed consent form will be provided in English and Chinese to the interview subjects for reference. The informed consent form contains the introductory statement and confidentiality statement for the interviewee to read. A phone will be used for recording purposes if the interviewee agrees to be recorded.

Preliminary Information:

Interviewers:
Interviewee:
Interview Date:
Location:
Audio Recorded by:

Translated by:
Transcribed by:
Transcription Date:

Permission to include interviewee's name in report:
Permission to use an audio and/or video recording of this interview:

Interview Questions:

1. 您在智慧停车系统的研究中负责哪些内容？
2. 贵公司会对杭州的智慧停车系统及其相关内容做出哪些贡献？
3. 您认为将来杭州的智慧停车系统会采用哪些科技？
4. 关于智慧停车系统，请为以下几项因素的重要性排序
    - 停车效率 [ ]
    - 便利性 [ ]
    - 价格 [ ]
    - 安全性 [ ]
    - 空闲车位数量 [ ]
5. 您认为停车场系统中哪些数据最为重要？
6. 您可否对我们的项目提出几个建议？

Appendix G: Researcher & Graduate Students Interview (English Version)

Planning Details:

The intended purpose of these interview questions is to guide the team to have a semi-structured interview with Research & Graduate Students. The team will ask to be accompanied by the sponsor, a Chinese buddy or a Chinese translator. A printed copy of the interview questions and the informed consent form will be provided in English and Chinese to the interview subjects for reference. The informed consent form contains the introductory statement and confidentiality statement for the interviewee to read. A phone will be used for recording purposes if the interviewee agrees to be recorded.

Preliminary Information:

Interviewers:
Interviewee:
Interview Date:
Location:
Audio Recorded by:

Translated by:
Transcribed by:
Transcription Date:

Permission to include interviewee's name in report:
Permission to use an audio and/or video recording of this interview:

Interview Questions:

1. What is your field of study?
2. What technology (software or hardware) is currently used frequently in smart parking within Hangzhou? (RFID, OCR, etc.)
3. What technology do you see being used in smart parking in the future for a better user experience?
4. Which technology is going to be the trend of the future, 5G or RFID? why?
5. What are the main issues with the current parking system in Hangzhou?
6. What are some potential vehicle navigation methods within parking complexes?
7. What problem might people have with new technologies in smart parking? Our team's hope is to create an efficient smart parking system solution that could be developed in the Internet of Things (IoT) characteristic town located in Hangzhou.
8. What suggestions do you have for our team's project?
9. How is technology used to make smart parking more convenient?

Appendix H: Research & Graduate Students Interview (Chinese Version)

Planning Details:

The intended purpose of these interview questions is to guide the team to have a semi-structured interview with Research & Graduate Students. The team will ask to be accompanied by the sponsor, a Chinese buddy or a Chinese translator. A printed copy of the interview questions and the informed consent form will be provided in English and Chinese to the interview subjects for reference. The informed consent form contains the introductory statement and confidentiality statement for the interviewee to read. A phone will be used for recording purposes if the interviewee agrees to be recorded.

Preliminary Information:

Interviewers:
Interviewee:
Interview Date:
Location:
Audio Recorded by:

Translated by:
Transcribed by:
Transcription Date:

Permission to include interviewee's name in report:
Permission to use an audio and/or video recording of this interview:

Interview Questions:

1. 您的主要研究方向是什么?
2. 杭州当前在智能停车系统中常使用使用哪些硬件技术？（如射频识别，光学文字识别等）
3. 您认为在将来会有哪些硬件技术投入使用？
4. 您对5G和射频识别有何看法？
5. 您认为当前杭州的停车系统存在哪些主要问题？
6. 您认为有哪些可行的室内停车位指引系统?
7. 新的硬件技术投入使用时，市民通常会作何反应，会遇到何种问题？
8. 您对我们的项目有何建议？我们的团队的最终目标是物联网特色小镇中创造出更加便捷的智能停车系统。
9. 硬件技术的投入是如何让智能停车更加便利的？

Appendix I: Parking Complex Naturalistic Observation Sheet

NATURALISTIC OBSERVATION OF PARKING COMPLEX by Smart Cities			
Observer:	Address:	Date/Time:	
Safety			
1. Is the parking lot well lit?		Yes	No
2. Are there poorly lit areas that pose a safety concern?		Yes	No
3. Are there easily visible exit signs?		Yes	No
4. Is there a fire prevention system?		Yes	No
a. Are they easy to find?		Yes	No
5. Were there any accidents/crashes observed?		Yes	No
7. Are there sufficient CCTV cameras?		Yes	No
8. Are the cars parked allotted reasonable parking area in each space?		Yes	No
Extra Notes:			
Infrastructure			
1. Is the parking lot beneath or above ground?		beneath	above
2. Is the parking open to natural light?		Yes	No
3. How many car entrances are available?		Number:	
4. How many floors are in the parking lot?		Number:	
6. Is the parking lot crowded?		Yes	No
7. What are the exit methods available for customers?			
8. Is the facility clean?		Yes	No

10. Is the parking complex on gravel, cement or other?		
11. How do cars go between floors? (spiral, ramps, etc)		
12. Are bikes and mopeds allowed in the facility?	Yes	No
13. What is the apparent wage demographic of the customer vehicles?		
14. Are the direction signals clear?	Yes	No
Extra Notes:		
System		
1. What technologies are present? (Bluetooth, RFID, OCR, etc.)		
2. Is there a car navigation system?	Yes	No
a. What localization technique does it use?		
b. What is the interface of the navigation system? (Big Screen/ Map/ Computer/Phone App/Other)		
3. Are there exclusive parking spaces with reservation techniques?	Yes	No
a. What technology is used?		
4. What payment method does the system use? (Toll Booth, Self Service, Smart Payment System, etc)		
a. What is the fee rate of the parking complex?	Chinese Yuan:	
b. Does the fee change for routine users?	Yes	No
Extra Notes:		

Appendix J: Industry Expert Interview Transcriptions with Coding Highlights

Industry Expert Interview with Backend Software Engineer of Hangzhou PShare Co.

Information:

Interviewers: Shuxing Li, Professor Liu
Interviewee: Jie Lu
Interview Date: Thursday, November 15th, 2018
Location: Hangzhou PShare Co.
Audio Recorded by: N/A

Translated by: Shuxing Li
Transcribed by: Shuxing Li
Transcription Date: Friday, November 16th, 2018

Permission to include interviewee's name in report: Yes, permission was granted.
Permission to use an audio and/or video recording of this interview: No.

Interview:

Q: What is your role at this organization?
A: The interviewee stated that he develops of the server-side software. The organization does not provide actual software but sockets that customer companies can connect to.

Q: What are your company's goals for developing smart parking in Hangzhou?
A: The interviewee claims that the company already has projects running across the country and the company will be focusing to look for new solutions and resolve existing problems of the parking system, especially the system of open parking lots (parking complexes that does not require any booths and stops.)

Q: What forms of future technology do you expect to see implemented in smart parking?
A: The interviewee believes that the current parking system for closed parking (parking complexes that require booths and stops) is well developed. However, open parking lots are still a problem. The interviewee believes that parking locks will become a trend in the future, but labor force might still be needed for the transitional period.

Q: Will the technologies conform in the future? In other words, will all the systems utilize the same type of technology?
A: The interviewee stated that the current transmission technologies such as LORA, RS485 or NB-IoT both have their pros and cons. For example, RS485 may require underground wiring but is more stable, while LORA is easy to deploy and is long lasting. Different parking lots will still have a different need, and a technology that can be used to solve the same problem does not exist

yet.

Q: Please order the following factors in order of importance for smart parking in China: parking efficiency, convenience, price, safety and availability.
A: The interviewee believes that safety is the most important, and then price, convenience, parking efficiency and availability.

Q: What type of data do you think is important in a smart parking system?
A: The interviewee believes that the data of parking time period can be very important. With user's choice of parking lots, the company might be able to develop a system that analyze customer's preferences of parking lots, such as the preferred parking price and parking lot location. By analyzing the data, the system can provide customers with recommendations of parking lots when they go out on a visit.

Q: Do you have any recommendations for our project team?
A: The interviewee does not believe that he can provide any technological recommendations for the project team. However, he believes that parking lot toll booth and parking locks combined can become a good solution for the IoT characteristic town. The toll booth can filter out whether the vehicle is an employee vehicle or a visitor vehicle. Then, the corresponding parking lock can be unlocked for the vehicle to park. OCRs can be used at the entrance to differentiate vehicles, or a digital license plate can be installed on vehicles. However, digital license plate might not be used widely for the current time being.

Expert Interview with Hardware Engineer of Hangzhou PShare Co.

Information:

Interviewers: Shuxing Li, Professor Liu
Interviewee: Zhanyi Shi
Interview Date: Thursday, November 15th, 2018
Location: Hangzhou PShare Co.
Audio Recorded by: N/A

Translated by: Shuxing Li
Transcribed by: Shuxing Li
Transcription Date: Friday, November 16th, 2018

Permission to include interviewee's name in report: Yes, permission was granted.
Permission to use an audio and/or video recording of this interview: No.

Interview:

Q: What is your role at this organization?
A: The interviewee stated that he develops hardware for the parking locks and design PCBs.

Q: What are your company's goals for developing smart parking in Hangzhou?
A: The interviewee claims that the company has already formed a complete system. He expects the company to create a complete smart parking solution in the future.

Q: What forms of future technology do you expect to see implemented in smart parking?
A: The interviewee expects the vehicles to include digital tags in the future for vehicle identifications. The system might be installed by the government, and the technology does not limit to RFID. The interviewee also has a high expectation for 5G transmissions, since it has a low cost and can be adapted to current technologies.

Q: Please order the following factors in order of importance for smart parking in China: parking efficiency, convenience, price, safety and availability.
A: The interviewee believes that parking efficiency is the most important, and then price, convenience. The interviewee also believes that safety and availability are far less important than any other factors.

Q: What type of data do you think is important in a smart parking system?
A: The interviewee stated that the data for the customers, such as the number of vehicles, the vehicle/available spots ratio is important for improving parking efficiency. With these data, a system can attract customers when it's empty, or guide customers away from it when it is full. Apart from this, vehicle demography is also important, as it can be used to attract luxury companies to start business there if many expensive vehicles exist in the parking lot.

Q: Do you have any recommendations for our project team?
A: The interviewee believes that given the prerequisite that big data is used widely, future technology can utilize 5G a lot, since it is efficient in transmitting data, and has a long range. The

interviewee also believes that the project should be government involved.

As for the interviewee's ideal solution, he believes that the current technology can accomplish quite a lot of things such as an OCR camera installed at the entrance and parking locks for reserved/private parking spots. The interviewee expects displays to be installed inside a vehicle and in door guidance system can be shown on the screen when a vehicle enters a parking complex.

Expert Interview with Hardware QA Engineer of Hangzhou PShare Co.

Information:

Interviewers: Shuxing Li, Professor Liu
Interviewee: Weijie Li
Interview Date: Thursday, November 15th, 2018
Location: Hangzhou PShare Co.
Audio Recorded by: N/A

Translated by: Shuxing Li
Transcribed by: Shuxing Li
Transcription Date: Friday, November 16th, 2018

Permission to include interviewee's name in report: Yes, permission was granted.
Permission to use an audio and/or video recording of this interview: No.

Interview:

Q: What is your role at this organization?
A: The interviewee stated that he tests products, improve their performance and is in charge of customer supports.

Q: What are your company's goals for developing smart parking in Hangzhou?
A: The interviewee claims that the company is aiming to fill in the blank for automatic/remote parking locks and improve parking efficiency. He also stated that the company is mainly in charge of circuit boards and systems, and manufacturing is done somewhere else.

Q: What forms of future technology do you expect to see implemented in smart parking?
A: The interviewee expect shared parking to be more common in the future, and the product they are developing – a parking lock that locks the car instead of locking the parking spot might become a trend.

Q: Please order the following factors in order of importance for smart parking in China: parking efficiency, convenience, price, safety and availability.
A: The interviewee believes that safety is the most important factor then convenience, parking efficiency, availability and price.

Q: What type of data do you think is important in a smart parking system?
A: The interviewee believes that the time period of vehicle uses, and the number of parked cars is important. He also stated that parking lots that have empty spots at night can also consider sharing parking resources to the public at night.

Q: Do you have any recommendations for our project team?
A: The interviewee believes that big data is highly important. He also claims that vehicle detection can be done with multiple ways, such as magnetic sensor, ultrasonic waves or radar. In

ideal situations, vehicles should have a location device itself, and digital fences can be used widely. The interviewee also stated that when wireless transmission became the trend, cameras might be used more for monitoring instead of doing character recognitions.

Expert Interview with CEO of Hangzhou PShare Co.

Information:

Interviewers: Mike Altavilla, Evan LeBeau, Josue Contreras
Interviewee: Hongcheng Shen
Interview Date: Thursday, November 15th, 2018
Location: Hangzhou PShare Co.
Audio Recorded by: Josue Contreras

Translated by: N/A
Transcribed by: Josue Contreras
Transcription Date: Tuesday, November 20th, 2018

Permission to include interviewee's name in report: Yes, permission was granted.
Permission to use an audio and/or video recording of this interview: Yes, permission was granted.

Interview:

Q: What is your role at this organization?
A: The interviewee is the CEO of PShare.

Q: What are your company's goals for developing smart parking in Hangzhou?
A: The interviewee claims that his company provides intelligent solutions for smart parking, both in hardware and software. The interviewee also stated that the company intends to develop a complete parking solution in the future.

Q: What forms of future technology do you expect to see implemented in smart parking?
A: The interviewee stated that a parking system is a complicated system. He believes that an ideal parking system will meet all customer requirements. He thinks that one technology cannot solve all the requirements, but a combination of technologies like Bluetooth, LORA and Zigbee could.

Q: Please order the following factors in order of importance for smart parking in China: parking efficiency, convenience, price, safety and availability.
A: The interviewee believes that availability has the highest importance because being able to recognize when a parking spot is open is important.

Q: Do you have any recommendations for our project team?
A: The interviewee stated that there are two kinds of parking problems that should be solved. The first one being the limited space and how to use this space to park more cars. The second problem is how to use the current parking lots and make them more efficient, in order to make the parking experience easier. He then stated that a parking solution is unique to the country, district or building because of the different requirements that have to be considered. He gave the example of a parking complex that is used by day for office employees and by night for residents

Expert Interview with employee at Alibaba

Information:

Interviewers: Shuxing Li, Mike Altavilla, Evan LeBeau, Josue Contreras, Professor Liu
Interviewees: Shuai Li and Li Yuan
Interview Date: Thursday, November 15th, 2018
Location: Alibaba
Audio Recorded by: Josue Contreras

Translated by: Shuxing Li
Transcribed by: Shuxing Li
Transcription Date: Friday, November 16th, 2018

Permission to include interviewee's name in report: Yes, permission was granted.
Permission to use an audio and/or video recording of this interview: Yes, permission was granted.

Interview:

Q: What is your role at this organization?
A: The interviewees are employees in the marketing department in Alibaba.

Q: What are your company's goals?
A: The interviewees claim that the company is more intended with the payment methods (Alipay), and the main business is online marketing, B2B, B2C and C2C. Alibaba also has department working on cloud computing.

Q: What types of future technology do you expect to see on cloud computing and payments?
A: The interviewees believe that payment methods are mainly used to reduce customer's cost of usage, such as the cost of having a smartphone. The interviewees expect facial recognition payments or fingerprint, or vocal print payment to become the mainstream in the future and expect payment to be done without any devices. The company is aiming to make payment more convenient and less people involved in the future.

Q: Do you think that the consumers would prefer a specific method of payment?
A: The interviewee stated that the preferred payment methods is highly depended on the situation. For example, a transaction with large amount of money may require more procedures. However, on a daily basis when the transaction amount is small, the payment method needs to be as fast as possible to improve user experiences.

Q: Are there any social concerns with future technology being implemented on things that have never done so before?
A: The interviewee stated that the current technology being developed in Alibaba are still in the stage of development and are not being used widely in the public, so he is unable to talk about the social concerns.
Q: Is there any way you can improve(patch) a system vulnerability in these future

technologies?
A: The interviewee believes that the development of a technology is an iterative process. The vulnerabilities will be fixed as the technology and laws becomes more complete, so the errors with technologies is not what he is worried about. The interviewee also stated that the public is less concerned with privacy than the public in the United States.

Q: Is there any data that shouldn't be collected by a parking lot?
A: The interviewee believes that all data should be collected (no data shouldn't be collected), and the public is not so concerned with privacy issues.

Q: Have you experienced any inconveniences when parking as a customer? Is there any way to improve it?
A: The interviewee claims that on a short-term basis, it is very difficult to find parking spots in a manual-driving car, especially on the weekends. To improve it in long term, auto driving may become the best solution, as it removes the process of parking a vehicle. To improve it in short term, the current goal is to connect parking lot data with the map and increase accuracy on parking space detection technology inside parking lots.

Appendix K: Research Students Interview Transcriptions with Coding Highlights

Researcher Students Interview at Smart City Research Center

Information:

Interviewers: Mike Altavilla, Evan LeBeau, Josue Contreras
Interviewees: Min Shi, Ruiqing Qiu
Interview Date: Monday, November 19th, 2018
Location: Hangzhou Dianzi University Xiasha Campus Smart City Research Center
Audio Recorded by: Josue Contreras

Translated by: Shuxing Li
Transcribed by: Shuxing Li
Transcription Date: Monday, November 19th, 2018

Permission to include interviewee's name in report: Yes, permission was granted.
Permission to use an audio and/or video recording of this interview: Yes, permission was granted.

Interview:

Q: What is your field of study?
A: The interviewees state that they work for localization technologies and parking space prediction methods for the parking complex.

Q: What technology do you see being used in smart parking in the future for a better user experience?
A: The interviewees introduced the project team to iBeacon, a bluetooth connection technology developed by Apple Inc. The research team developed a deployable beacon that uses this technology. The beacon utilizes Bluetooth connection with smart phones. The beacons have a range of 90 meters and can be placed within the parking lot to accomplish indoor localization methods. Currently, a dedicated smart phone application is available to the users.

Q: Which technology is going to be the trend of the future, 5G or RFID? why?
A: The interviewees believe that 5G will definitely become the trend, as it has a low delay, high capacity and low cost. Besides, 5G can smoothen the process of human to human or human to object communications.

Q: What are the main issues with the current parking system in Hangzhou?
A: The interviewee believes that the major problem is that there is too many people in China, and parking spot management can become a difficult problem. Besides, parking space management and parking space guidance are currently done by labor forces. It would be better if the management can be done by a smart system.

Q: What are some potential vehicle navigation methods within parking complexes?

A: The interviewee stated that a public notification board can help with the navigation, which is the current technology utilized in Hangzhou. The interviewee also pointed out the fact that there are people who are working on developing a software solution for parking guidance and will make vehicles spread more evenly across the parking lot.

Q: What problem might people have with new technologies in smart parking? Our team's hope is to create an efficient smart parking system solution that could be developed in the Internet of Things (IoT) characteristic town located in Hangzhou.
A: The interviewee stated that when a technology is working perfectly, the public will usually accept the technology. However, when it works poorly or have a high cost, the people will less likely to accept the technology. In a long-term, if the technology have more benefit than drawbacks, it will usually be accepted by the people.

Q: What suggestions do you have for our team's project?
A: The interviewee suggested the project team to focus on the cost of the hardware and the flexibility of the software.

Q: How is technology used to make smart parking more convenient?
A: The interviewee gave the example of their beacon again. The beacon has a low price and is easy to be deployed. The interviewee mentioned that the price is around 38 yuan each device, and it only cost a total of 100,000 yuan to cover a parking lot of a size of the Hangzhou Railway Station (approximately 340,000 m^2).

Appendix L: Customer and User Survey Responses Sheet

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Subjects	Parking Lot	What Vehicle?	Usual Parking Spot	Why Parking in this Parking Lot?	Do You Live(Work) Near this Parking Lot?	Technology Sufficient?	Any Inconveniences?	Hard to Find Empty Spot? (0-Easy, 10-Hard)	Easy to Find Your Car?	Safety Issue (0-Not Safe, 10-Safe)		Side Notes
2											Vehicle Safety	Personal Safety	
3		JHP = Jinhui Parking Building, PPP = Peace Square Public Parking Building, QHB = Qiantang Hangkong Building, QTT = Qianjiang New Town Time Square											
4	Subject 1	JHP	Regular Car	Private	Official Business	No	Yes	N/A	8	Yes	NO DATA	NO DATA	
5	Subject 2	JHP	Regular Car	Streets	Official Business	No	Yes	N/A	7	Yes	8	7	
6	Subject 3	JHP	Electric Car	Streets	Charging Only	No	Yes	N/A	5	Yes	8	10	
7	Subject 4	PPP	Regular Car	Commercial	Business	Yes	Yes	N/A	2	Yes	10	10	
8	Subject 5	PPP	Regular Car	Commercial	Business	Yes	Yes	Too many entrances/exits makes the parking complex confusing.	6	Yes	10	10	
9	Subject 6	PPP	Regular Car	Commercial	Company is Nearby (Convienence)	No	Yes	N/A	7	No	5	7	
10	Subject 7	PPP	Regular Car	Commercial	Convenient	No	Yes	N/A	3	Yes	10	10	
11	Subject 8	PPP	Regular Car	Commercial	Business	Yes	No	Pedestrian share space with cars which makes it very dangerous. Also, there is no way to tell floor availability.	1	Yes	10	10	
12	Subject 9	PPP	Regular Car	Commercial	Business	Yes	Yes	N/A	3	Yes	6	7	Company can rent spot for parking, so it's free for their employees.
13	Subject 10	PPP	Regular Car	Commercial	Easy access to the (subject's) company (Convienence)	Yes	No	Hard to find parking spots when going to a parking lot for the first time.	9	No	10	10	The expense is high.
14	Subject 11	QHB	Regular Car	Private	Convenient	Yes	Yes	Private parking spot sometimes got used by other people.	7	Yes	8	9	
15	Subject 12	QHB	Regular Car	Shared	Convenient	Yes	No	Hard to find parking spots and expense is high.	6	Yes	8	10	
16	Subject 13	QHB	Regular Car	Shared	Work nearby, convenient	Yes	Yes	Temporary parking cars park in private spots. Parking complex get's clogged when leaving from work.	5	Yes	7	8	
17	Subject 14	QHB	Regular Car	Streets	Work nearby, convenient, surrounding area have less parking lot	Yes	No	Cannot find his own car and parking fee payment method is not convenient.	8	No	6	5	
18	Subject 15	QTT	Regular Car	Shared	Convenient, need to resolve something here so parked here.	No	Yes	Passage can be jammed in peak hours, not many parking space available, parking fee is high and hard to find car.	6	No	8	8	
19	Subject 16	QTT	Moped	Commercial	Convenient, has security people taking care of it.	Yes	Yes	N/A	1	Yes	10	10	
20	Subject 17	QTT	Regular Car	Private&Street	Other parking lot have no available spaces.	No	No	Hard to find parking spaces and own car.	8	Yes	8	7	

Appendix M: SWOT Analysis of Communication Technologies

Fifth Generation of Cellular Communication (5G) SWOT Analysis

Fifth Generation of Cellular Communication (5G)

	HELPFUL to Achieving the Solution	HARMFUL to Achieving the Solution
INTERNAL FACTORS	S • Easily integrated with existing hardware • Fast data transfer • Long distance communication • More bandwidth per device • Low latency • Lower device costs	W • Still being researched • High cost of developing infrastructure • Security and privacy issues have not been resolved
EXTERNAL FACTORS	O • NB-IoT integration • Network splicing • Great potential to be scaled • Major influence in IoT development	T • Current phones don't support 5G • Currently being limited by government and politics

Radio Frequency Identification (RFID) SWOT Analysis

Radio Frequency Identification (RFID)

	HELPFUL to Achieving the Solution	HARMFUL to Achieving the Solution
INTERNAL FACTORS	S • Low cost passive system • Low maintenance, long lifespan • Fast scanning rate, convenient • No line of sight limitations • Well developed in automotive industry	W • Can't scan through certain metals • Tag collision • Easily manipulated • Not standardized frequency
EXTERNAL FACTORS	O • Research show possible government incentive to develop RFID • RFID currently used in majority of parking places, incentive to have universal parking solutions	T • RFID is becoming outdated • Smart solutions going toward removing hardware

Bluetooth SWOT Analysis

Bluetooth

	HELPFUL to Achieving the Solution	HARMFUL to Achieving the Solution
INTERNAL FACTORS	S • Supported by many phones • No required line of sight • Free communication protocol • Allocated frequency band	W • High power consumption • Low range of communication • Set number of devices in network • Moderately slow transmission speeds
EXTERNAL FACTORS	O • Emerging in current smart parking developments • Currently developed and expecting continued integration • Development of Bluetooth 4.0	T • Easily manipulated, relies on device level security • Independent mobile device communication protocol -inconvenient

Appendix N: SWOT Analysis of Sensing Technologies

Ultrasonic SWOT Analysis

Ultrasonic Sensor

	HELPFUL to Achieving the Solution	HARMFUL to Achieving the Solution
INTERNAL FACTORS	S • Well used in motor industry • Cheap • Physical detection methods • Consistent • Not easily impacted by environment • Supports any type of surface material	W • Easily affected by temperature • Limited range • False readings on curvature surfaces (such as cars)
EXTERNAL FACTORS	O • Can connect to NB-IoT • Well developed in multiple industries	T • Little focus of future development

Infrared Sensor SWOT Analysis

Infrared Sensor

	HELPFUL to Achieving the Solution	HARMFUL to Achieving the Solution
INTERNAL FACTORS	S • Relatively cheap • Low power consumption • Reliable at both day and night • Responsive • Physical detection method	W • Can be affected by the particles (smog, fog, dust, etc.) • Require remote line of sight • Short range
EXTERNAL FACTORS	O • Well developed in multiple industry • Lower cost based on further development	T • Not widely used in parking industry • Little focus on future development • Few instance of implementation

Electromagnetic Sensor SWOT Analysis

Electromagnetic Sensor

	HELPFUL to Achieving the Solution	HARMFUL to Achieving the Solution
INTERNAL FACTORS	S • Easy to install • Well protected • Wireless • Long battery lifetime • Not impacted by the weather • Responsive and have few number of false readings • Well used in parking industry	W • Expensive • Lower tolerance of reading
EXTERNAL FACTORS	O • Multiple recent smart parking companies have success on using them	T • Most smart parking company use a partnering technology with the electromagnetic sensors.