IMPROVED RFID SMART PARKING SYSTEM FOR THE CITY OF HANGZHOU

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ABBREVIATIONS & NOTATIONS

AI: Artificial Intelligence
HDU: Hangzhou Dianzi University
IoT: Internet of Things
RFID: Radio Frequency Identification
PGIS: Parking Guidance and Information System
WPI: Worcester Polytechnic Institute

CHAPTER 1: Introduction

The modern city was created as a result of rapid industrialization and increased population density around production hubs such as ports. 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 countless companies constructed each year, modern cities have become overcrowded for residents and visitors. 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 network applied technology and collect data 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 own a driver's license in China, which has increased by 11.84% in less than 1 year (Gao, 2018). Hangzhou's size has led to a limited number of parking spaces that decreases further each year with the increased number of vehicle registrations.

High population density environments such as Hangzhou typically result in 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, and an illustration of the city's needs to support their populations. 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 need for a smart city is motivated by a rapid increase in population and urbanization. The concept of a smart city is fluid, as it conforms to the needs of its present population. 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 an increasing middle class. Once vehicles became more of a social normality, simple parking solutions were integrated into the city management plan. With the rapid growth of registered vehicles, the need for the more efficient parking solutions has become far more relevant. Researchers have begun developing smart parking solutions that are expected to increase parking efficiency and alleviate unnecessary city congestion. While technologies are still in development, Hangzhou traffic declined 12.5%, even when the population grew by 3% in 2018 through the implementation of smart parking (Hao, 2018). This relationship justifies that continued improvements to the smart parking solution creates a positive trend in mitigating city congestion despite an ongoing increase in population.

The rapid growth of Hangzhou's population and the subsequent registered vehicles has drawn a lot of attention to the inefficient current parking solutions. With an estimated 30% of traffic in urban settings due to vehicles searching for parking, a large portion of the city congestion could be mitigated by a solution that assists in finding available parking (Vesco, 2015). Many 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. Through incorporating this information, various parking complexes across the city could interconnect to decrease traffic congestion and improve parking convenience.

The smart parking solutions implemented into Hangzhou previously dealt with using simple 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 researching technologies that improve parking management across the city. A centralized system would have the ability to remove extraneous management personnel and improve vehicle safety. The system would also have the ability to integrate with a user interface that could provide drivers with information regarding parking options. These options would direct customers to desired parking spots based on price and convenience.

This project focuses on studying modern RFID technologies and suggesting possible improvements to the smart parking solutions in Hangzhou, China. With the help of the Smart City Research Center of Zhejiang Province, our team aims to explore the needs of Hangzhou citizens, and evaluate recommendations that address challenges with the current parking system. The team will consult the key stakeholders of the surrounding community in order to develop an understanding of the current smart parking systems and their challenges. Research will be conducted to determine RFID smart parking solutions that would be feasible within Hangzhou. The optimal solutions will be derived through supportive analysis consisting of a cost-benefit analysis and SWOT analysis. The final recommendation will be a RFID smart parking system that aims to alleviate city congestion and improve everyday life.

CHAPTER 2: Background

This chapter outlines the universal concept of a Smart City and what technologies could be used to cultivate an improved parking system. We describe the historical background of Hangzhou and explain the demand for smart city implementation within China. Furthermore, we analyze successful smart city developments around the globe and the impact applied technology has on community needs. Our team assesses RFID technology and highlights its role within developing smart parking systems. We support these ideas by evaluating the laws and regulations surrounding parking and technology within China; along with their place in verifying the feasibility of an integrated city parking network.

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 (Glasmieer, 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 developing 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). Alongside this, 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 are interconnected 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). Even though multiple of these pillars have been studied, most smart cities focus on a few or even one pillar (Northcott, 2017).

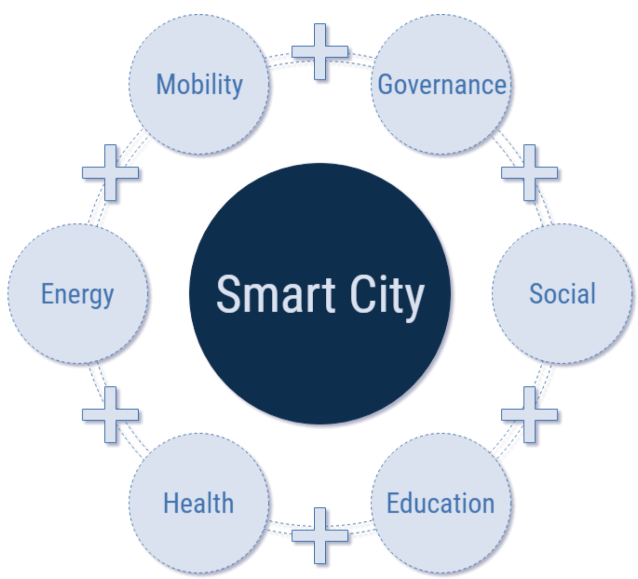

Figure 1: Six Pillars of a Smart City Diagram

Our team's project scope directly relates to the Mobility pillar shown in figure 1 and more specifically how smart parking spaces improve the city's overall efficiency. With this in mind our team will consider 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 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 cities 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 development 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). Some 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 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 are mostly focused 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 the 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 were made in hope of creating an interconnected and more efficient city. All developing smart cities, including Hangzhou, face challenges when implementing new technology into their society's.

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 is a big issue in China currently and these smart cities are focusing their research on finding unique solutions that adapt to each city's infrastructure.

Shanghai

Shanghai is a developing Smart City in China. 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 China and has reduced manpower costs that included parking supervisors and toll collectors (Lin, 2018). Smart city developments are typically influenced by the advances of neighboring cities. The developments implemented in Shanghai are directly relatable to the needs of Hangzhou.

Hangzhou

Hangzhou is also a developing Smart City in China. 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 also allows high priority vehicles like ambulances or police cars by allowing 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 more of a 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 a mobile application that navigates a user to an available parking space near their destination.

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.

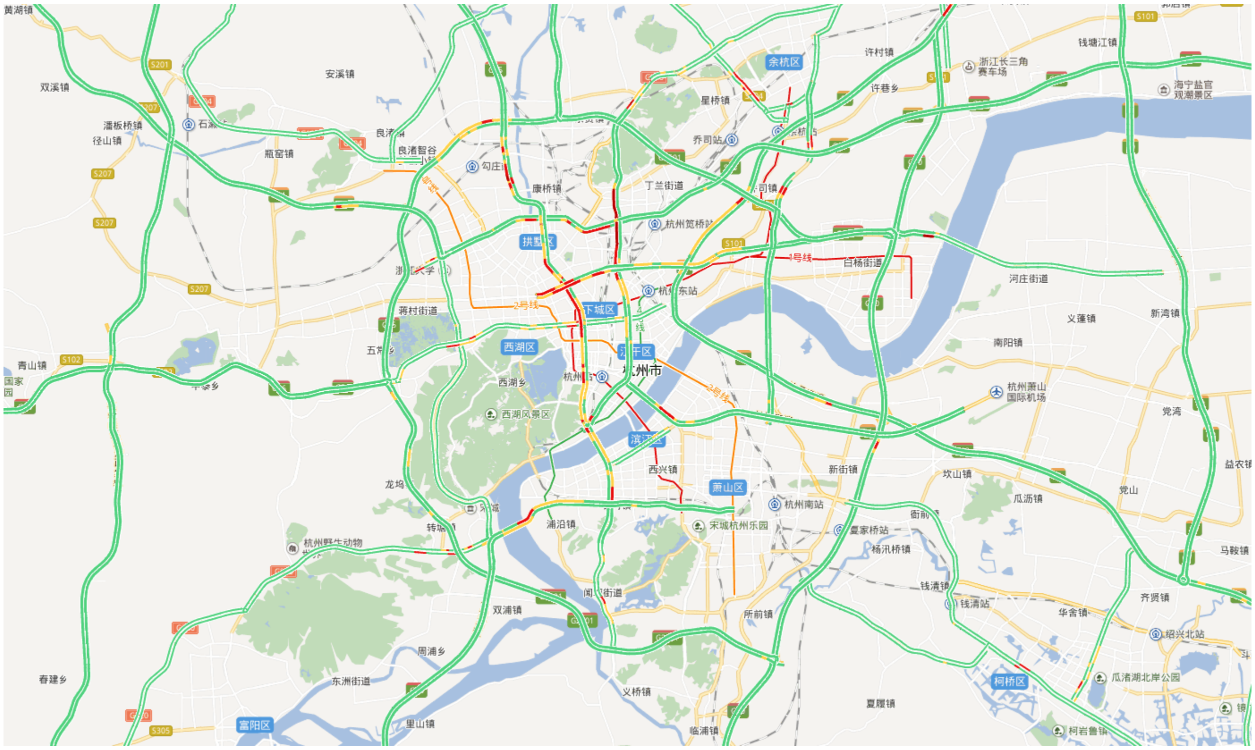

Figure 2: City congestion status in Hangzhou China, 10:00 AM

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 has been increased by 5% (Hangzhou City Government, 2018). Since these non-contact parking payment systems have shown an increase in efficiency, the Hangzhou Smart City Research Center is now focusing on the overall parking experience. The research center has sponsored our team in order to construct solutions that aim to relieve the need for security personnel and improve the process of finding an empty parking space.

2.3 Current Smart Parking Solutions

2.3.1 Smart Parking Systems

When investigating potential improvements to be made to 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. While these systems vary greatly across locations, the fundamental components of the systems can be split into five broad categories: 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. These systems are unique because they are utilized in both decentralized and centralized systems. The decentralized systems are categorized as such because they focus on one parking facility only. 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 information is updated in real-time in order to guide the driver to a parking space that is calculated through 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. EZPass is a system that allows customers to register their vehicle online to receive an RFID tag. This RFID tag is pinged by RFID readers located on highways and parking facilities. The RFID readers then use this information to charge the driver for the designated fee without the use of personnel. Payments are enforced through email and text communication for easy access by both managers and consumers. Smart payment systems reduce traffic congestion by improving traditional parking system payment methods and offering customers a more convenient and fast way to pay (Leng, 2009). While these payment systems have resulted in reducing traffic congestion, some implementations have also resulted in mandatory passes and penalty fees.

2.3.5 E-Parking

E-parking is a system type that has been commonly implemented in cities, university campuses, and traditional parking complexes. E-parking allows customers to determine the availability of a parking space and/or reserve that space. The 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 into, a driver can conveniently register for a space. RFID tags are used to control access by only allowing vehicles to enter the facility with a registered RFID tag. E-Parking systems are being implemented into mobile applications that allow users to reserve parking spaces at the click of a button. The functionality of E-Parking has room for exponential 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 the vehicles are parked by computer-controlled mechanisms. 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 are automated by robotic parking systems or revolving parking systems. 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 implications of a computer taking 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. Mobile applications began to attract people's attention rapidly in the automotive industry in 2009 when Uber was founded. Uber is currently worth over $40 billion and if it were a public company as opposed to private, it is estimated that it would be ranked number 367 (Lashinsky, 2018). 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 is estimated to cause 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. There have been simulations conducted by researchers in other parts of the globe indicating 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). Our sponsor aims to create an app primarily for Hangzhou that mitigates city congestion, improves vehicle access data, and reduces management personnel. The current scope for the app is Hangzhou, however the app could have the potential to span across the country of China, or even globally if it is effective.

2.3.8 Shortcomings and Issues of Networked Smart Parking

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 while individual complexes have integrated smart technology to improve management, there have been few major improvements to city wide integration of the data collected in smart garages.

One notable contribution to creating a citywide parking management solution has been the integration of mobile applications into parking garages. Parking complex managers in China have been using new technologies to update their available parking spot quantities in real-time. The ability to detect which complexes have available parking has been implemented into a handful of mobile applications that have been providing this information to the public on a convenient platform. Currently there are a handful of Chinese apps in use (U-parking, ETCP, etc.), all of which lessen the load of city congestion as drivers are more easily directed to open spots (Xuequan, 2018). While this solution is adequate at creating a more efficient parking direction system, it's clear that these applications haven't been fully integrated into the smart parking technology that many complexes are adopting. In short, smart parking systems are developing on a centralized level, but little advances are being made in connecting the implemented technologies.

2.3.9 Opposing factor to Smart Parking Development

Another notable obstacle to the efforts being 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, it's noted that 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 produces 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 are significant efforts that need to be made by

Chinese citizens to fully utilize the smart parking technologies that are being put in place (Yang & Huang, 2017). In order for current and future smart parking technologies to create an impact on city efficiency, they must be socially accepted and continually put to use by the city occupants. Creating a socially accepted parking solution can be aided through improvements to both the hardware and software systems in place throughout the city.

2.4 RFID Hardware Solutions

2.4.1 RFID High Level Overview

To understand the basic structure of RFID hardware, it's 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. The reader module itself is a powered device which emits electromagnetic waves which can vary in frequency depending on location and application. Subsequently, the tags contain owner specific information and are distributed by the system managers. RFID technology is commonly used for vehicle identification and management within parking complexes. 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.

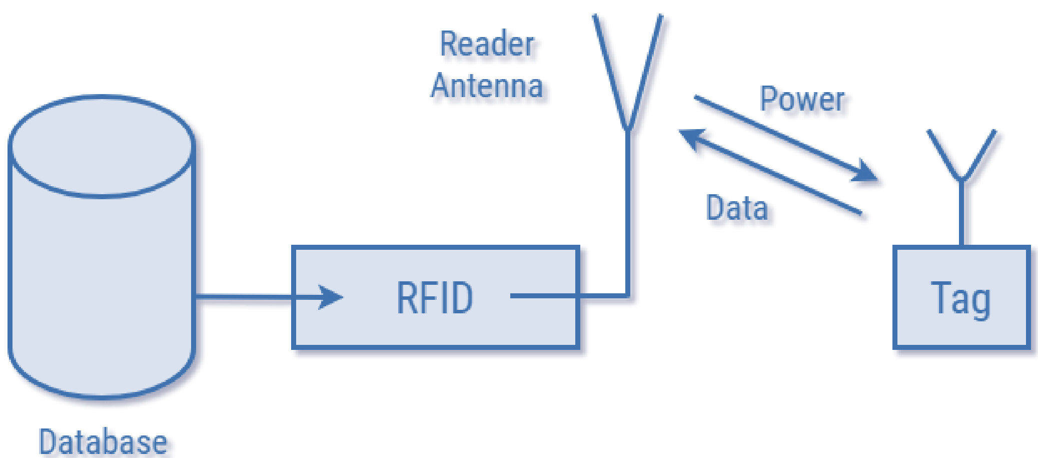

Figure 3: High level RFID System Overview (Boularess, Rmili, Aguili & Tedjini, 2015)

2.4.2 Passive, Active, and Semi-Active RFID

The hardware developed to support modern RFID infrastructure can be characterized as passive, active, or semi-active technology. Identifying RFID tags as either passive or active is determined through 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 enough 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 distinction between semi-active and active RFID tags is determined through the tags role in the system. 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. This category of tag is often known as a transponder, as it acts a beacon when activated by a reader in its general proximity.

2.4.3 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 it's clear that active and semi-active RFID tags are a superior hardware solution in terms of wireless connectivity, it's important to consider the additional costs. The need for an onboard power source and active transceiver means that each tag comes a significantly higher price tag in comparison to passive tags. For this reason, 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). While all RFID technology can be compromised, the manipulation of passive tags has been publicly known for years.

2.4.4 RFID Hardware in Smart Parking Systems

When considering RFID hardware applied to smart parking, both active and passive technology have been implemented into modern management 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 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 marking 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, and network connected parking management systems.

2.5 RFID Infrastructure

2.5.1 RFID Host Computer

In a modern RFID parking system, there is typically a host computer positioned within the facility near the RFID readers. The readers send information to the host computer to be processed, organized, and positioned in a queue. By performing these functions, the host computer serves as a monitor for ensuring that the reader is functioning properly, securely and with 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. When analyzing the different RFID system currently implemented in Hangzhou, our team will need to evaluate the host computer’s process. If a centralized system is made that spans multiple parking systems, the host computers will need to provide all of the data required to ensure successful operation. This data obtained filters in tandem with the middleware of the RFID system.

2.5.2 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 middleware is commonly installed on the host computer or the RFID readers, but sometimes both. 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 be allowed access between 9am-9pm, at 10pm the vehicle should not be allowed to access the parking complex. The middleware is programmed by an engineer to meet these logic requirements.

2.5.3 Centralized and Decentralized Systems

A centralized system consists of all data from an organization residing in a central location. An organization owner that has many different facilities would store all the data from each facility in one datacenter, as opposed to having data isolated at each location. The purpose of a centralized repository is that the data becomes easier to use and manage. With all of the data in one place, a manager can easily remotely access and administrate the system. This ease of access is important to keep in mind when analyzing RFID systems, as administrators could view vehicle identification and monitor the efficiency and functionality of the system remotely (Pala, 2007). This in turn helps decrease the cost of a system design as it offers the option to cut extraneous personnel. Instead of having administrators at each location of a parking complex, a parking organization could centralize their administrators in one location and filter all the complexes' data through that location. Centralized systems are restricted around the globe as different data accessibility and regulations laws are in place to protect user information. These systems also pose a high security risk, because if the system is breached then all the stored information is vulnerable. This is a large concern with centralized systems when they are guarding highly sensitive data such as personally identifiable information. There is also a large chance of downtime within a system when all the data is stored in one place. Downtime is when a system is malfunctioning, and all its data is therefore inaccessible or halted. Downtime can result in an extreme loss of revenue for a system manager, as well as general inconveniences for customers.

A decentralized system consists of data residing only at the location that it was created. Decentralized systems primarily attract organization owners that want to process their data independently at each location. This processing helps to localize and analyze data because of the data being stored at its source. Performance analysis of the RFID system within a certain complex can be easily performed and concluded than when the data is centralized. There are also security perks to a decentralized parking system because in many implementations, if the data is breached then only the data within that system is vulnerable. This same concept applies to downtime of the data, as if one system is down due to a malfunction, the rest of the systems will still be up. The major downfall of a decentralized system is the "lack of standardization for reporting across business units, lack of common enforcement of data governance policies and redundant infrastructures" (Lockner, 2015, p. 22). If an RFID system is decentralized the lack of standardization would make it hard for the systems to be consistent across multiple complexes. The lack of standardization in turn over time would require a much higher amount of funding in order to manage the data.

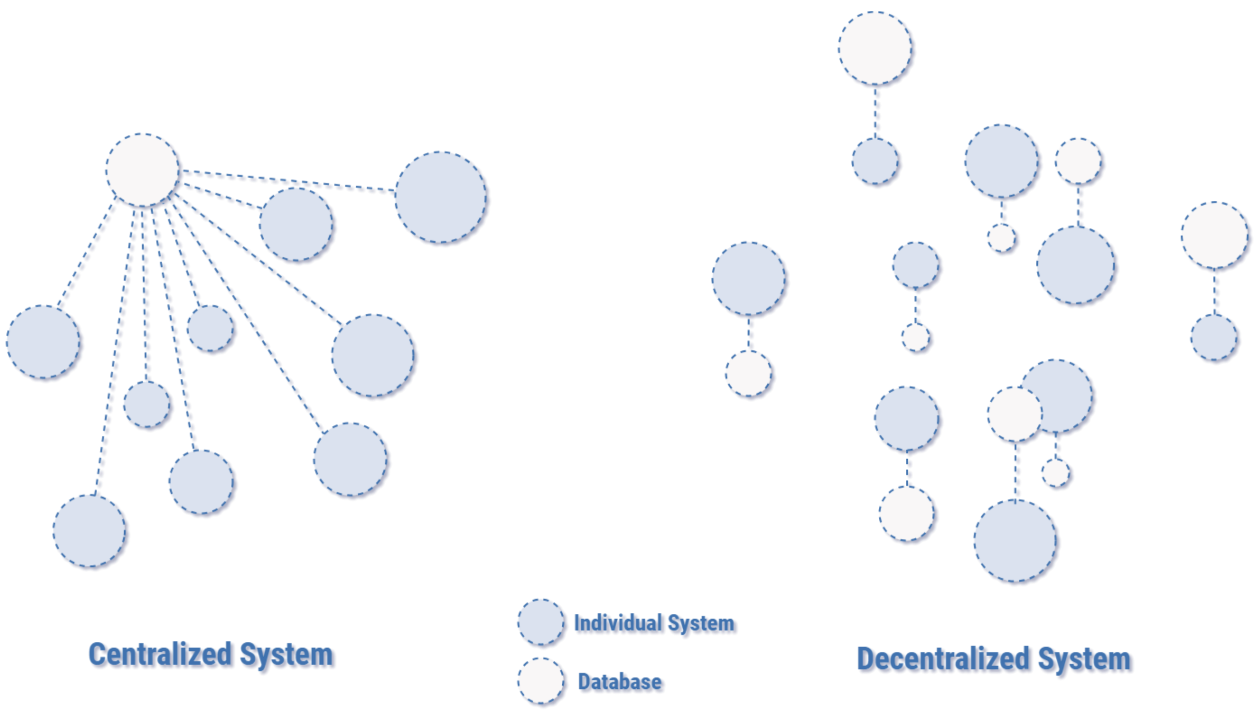

Figure 4: Centralized vs. Decentralized Systems

2.6 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 (Glasmieer, 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 as a, "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 a local database that can be accessed and later shared with other databases if needed; this demonstrates the capability of communication between systems. Subsequently, the RFID reader retrieves data with a specific Electronic Product Code (EPC) from location where the server can connect with the RFID tag. EPC is a unique number given to the RFID tag in order for systems that are compatible can retrieve the data from the local server (Fabain, 2010). The capabilities for a system that uses IoT with RFID are endless, and if implemented correctly, can improve the system overall. Furthermore, these systems are typically tailored to a specific city or region, as there are specific laws and regulations which must be considered when integrating RFID networked technology into any system.

2.7 Local Regulations

2.7.1 Local Laws Regarding Parking

While advanced technology has made an impact in smart parking systems, local laws and regulations have a large restriction on these systems' implementation. The local laws determine where a new smart parking system can be implemented and what kind of technology can be used. 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 3 laws regarding illegal parking: No. 33, No. 56 and No.93.

China's law No.33 states that newfound public service buildings, shopping areas, residential areas and massive structures are required to build parking lots. If the parking lot does not offer sufficient parking spots, landowners are required to expand or rebuild as soon as possible. Fully functional parking lots may not be shut down privately or modified to serve functions other than parking. The government can assign parking spots on the streets as long as it still satisfies the need of traffic fluidity.

No.56 and No.93 talk about regulations regarding illegal parking. Motor vehicles must be parked on dedicated parking areas and may not be parked on the sidewalk, except for parking lots that are mentioned in law No.33. If a driver left their vehicle parked 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. The direct relationship between legal parking and city-wide parking management is qualified by the efficient use of available parking spots.

2.7.2 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 2 regulation laws regarding proper and permitted usage of Radio Frequency. 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 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 frequency, which RFID technologies are built on, does not require gaining any permissions.

2.8 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 to be implemented 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 focuses on studying modern RFID technologies and suggesting possible improvements that could be made to the smart parking solutions in Hangzhou, China. With the help of the Smart City Research Center of Zhejiang Province, our team aims to explore the needs of Hangzhou citizens, and evaluate recommendations that address challenges with the current parking system.

The final project deliverables are a written report and presentation that propose recommendations of RFID-based intelligent parking systems that could improve vehicle safety, vehicle access data/statistics, and ultimately traffic efficiency.

The following diagram displays the objectives presented that will guide the project:

Figure 5: Project Goals and Objectives Flowchart

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

In order to accurately approach our project goal of developing smart parking solutions for the city of Hangzhou, it is important for the team to have a concrete understanding of the current technology being applied within the city. With a proper foundation of knowledge pertaining to the current developments, and needs of the applicable parties, the team will be able to properly approach developing recommendations that create a feasible and effective smart parking system.

The team will first perform naturalistic observation that targets the current systems and their consumer interactions. The team will conclude considerations from this data to guide the research and development of potential RFID solutions. Additionally, the project team will be tasked with conducting interviews targeted at relevant stakeholders such as IoT experts, customers, and developers of smart parking complexes.

Figure 6: Objective One Flowchart

3.1.1 Observe Everyday Customer Interaction with Parking Spaces

Hangzhou will be a new environment for the entire team. With this in mind, the team expects to witness significant cultural differences present in city life. The team plans to perform a naturalistic observation to observe traffic patterns, driver behaviors, and the interaction between citizens and parking systems. Through this observation, the team will gain a better understanding of the needs of Hangzhou as a city.

3.1.2 Select Interview Subjects

IoT Experts

As previously discussed, a portion of the research will deal with focusing on the networking of current and future smart parking solutions. Considering the fact that increased city efficiency can only be achieved through interconnected technology seen in city wide parking complexes, it’s important for the team to research Internet of Things experts. Companies such as

Netease, Alibaba, and Huawei all have significant resources invested in the development of Internet of Things technologies. By consulting these experts on current developments within the industry, the team will gain a better understanding of how upcoming networking solutions can be leveraged to create a more unified city-wide parking management system.

Hangzhou Citizens

With any commercial development project, it's important to consider the consumers of the product. In this case, the citizens of Hangzhou can provide firsthand information on the shortcomings of current systems which affect their daily life. With this in mind, the final recommendations will need to pertain to the needs of the public, as a smart city solution is successful when used by a significant amount of the population. Hangzhou citizens will be selected from a convenience sample in order to accurately represent the general population's opinion. Gauging the public opinion on what features and improvements appeal to the average customer allows for the team to connect proposed solutions to the social aspect of smart parking integration.

Graduate Students at HDU

The team is fortunate enough to have the resources of HDU's smart city research center at its disposal. The team will interview the research students who have been already developing RFID solutions in order to gain a better understanding of the sponsor's progress. Through interviewing the current graduate students, the team hopes to develop an understanding of the research's key focus areas. While the research performed by these students is noted to be primarily highly technical developments, the underlying challenges addressed should pertain to the team's overall project goals.

City Planners

A majority of the project's challenges arise from a lack of sufficient parking spaces in Hangzhou. When it comes to the physical developments of smart parking complexes, city planners typically handle the research involving site location and potential investors. The team plans to interview city planners and draw conclusions on the design process of city parking complexes. Additionally, the team plans to obtain a well-formed understanding of how laws affect parking development.

3.1.3 Consult Primary Stakeholders

Industry Interviews

The team will be taking part in sponsor facilitated interviews with IoT experts in Hangzhou China. During these interviews the team plans to obtain information pertaining to the feasibility and research of RFID technology currently being used in Chinese parking complexes. Gauging the effectiveness of RFID as an applied technology will allow the team to consider how final recommendations will differ from current solutions. Additionally, considering IoT companies do not strictly use RFID technology, the team plans to ask questions regarding what other technologies are currently being used. Holding these discussions with IoT experts will allow the team to get a better sense of RFID-based smart parking solutions that could have the ability to communicate with each other in Hangzhou.

Furthermore, the team plans to interview the managers of these systems, as they interact with the current smart parking systems daily. Interviewing the parking complex managers will allow the team to gain knowledge of the operational shortcomings, and the current level of intelligence of smart parking systems in Hangzhou. The team's background research displays a variety of present smart parking systems that are currently offered. Through consulting the managers of Hangzhou's parking spaces, the team expects to gain an understanding of which current systems are the most effective, and their defining characteristics.

Public Surveying

Considering the information we collect during expert interviews will be derived from the opinions of a few expert individuals, our team will obtain data that represents a larger audience through public surveys. Parking complexes have become a common strategy to consolidate parking spaces within cities. Due to their widespread use, the team plans to obtain the opinions of parking complex consumers. Smart solutions require the public's widespread use, and thus final recommendations must be developed with the user's needs in mind. The team intends to offer simple research questions to the users of parking complexes, and ultimately determine recurring trends.

3.1.4 Conclude Consumer Needs

Drawing conclusions between observed and surveyed customer data will prove to be a major portion of the team's evaluation of consumer needs. The team will analyze the recorded data and recognize parallel trends between the system characteristics that appear most often. The analysis will primarily consist of a trend analysis, to determine trends amongst the stakeholders and to conclude the considerations needed for further research. If a specific customer need is witnessed in a large portion of surveys and observations while in Hangzhou, the team will acknowledge and leverage the data point to focus research towards the optimal solution.

In addition to analyzing the relationship between surveys and naturalistic observation, the team will consider how the needs of consumers and providers relate. By noting a similar need in both parties, the team will be better prepared to develop solutions which are best suited for both the developers and users of future smart parking complexes. In doing so, the team will also touch upon the progress and goals of developers currently working on improved smart parking technologies. Being cognizant of these ongoing developments will allow the team to provide solutions which are up-to-date and most effective in supporting the growing population of Hangzhou.

3.2 Objective Two: Evaluate Potential RFID Solutions to Increase Smart Parking Efficiency

The team will determine considerations based on the information collected from surveys, interviews, and observations to develop an understanding of important factors needed in an RFID-based smart parking system. Research will be conducted to determine solutions that can be implemented to address current parking challenges in Hangzhou. The team will verify the feasibility of potential improvements, which will help filter ideas down to concrete solutions. This section of the project illustrates how the team will develop solutions, which will then be analyzed and presented in objective three.

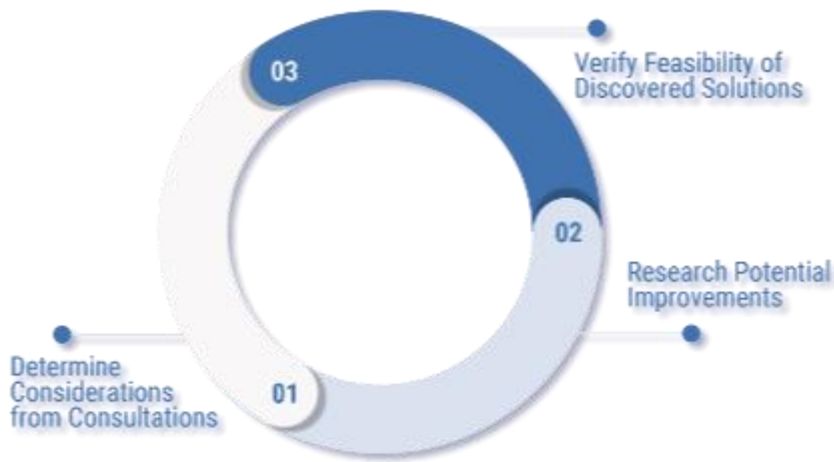

Figure 7: Objective Two Flowchart

3.2.1 Determine Considerations from Consultations

In order to evaluate solutions that could improve the parking system, the team will need to consider the data obtained from the interviews, surveys, and observations. The consultations performed will provide crucial information that will need to be considered when determining potential solutions to the current parking challenges in Hangzhou. The following are the primary considerations that will be taken into account:

- Technical suggestions from experts
- Stakeholder needs
- Concerns expressed by any involved parties
- Universal trends witnessed through observation

These considerations will be compiled in a multi-criteria evaluation. This evaluation is displayed in the table below, which organizes the data obtained into a compressed format. The table will categorize the data by the considerations noted above. These categories will be organized by technical suggestions, stakeholder needs, and concerns discovered through interviews and surveys. By cross-referencing different interviews and surveys, the team will have a category for recurring trends that were witnessed. These trends will be supported and qualified by data obtained through naturalistic observation. By compiling all this data into a table, the team will be able to develop an understanding of important factors to consider when evaluating potential improvements that can be made to the smart parking system.

	Technical Suggestions	Stakeholder Needs	Concerns	Universal Trends
Citizens				
Customers/Users				
Parking Space Personnel				
Public Parking Space Managers				
Research & Graduate Students				
Tech Company Experts				
IoT Experts				
Government Officials				
Naturalistic Observation				

Table 1: Considerations Table

3.2.2 Research Potential Improvements

After reviewing the factors that need to be considered, the team will begin to research potential improvements to the smart parking system. These improvements could be in the form of simple alterations to specific elements of the parking system, or in the form of an entirely new system. The team will begin researching improvements by evaluating parking systems currently in use and will evaluate the current software and hardware of the smart parking systems. This evaluation will break down the systems into why they are being used, the benefits of the systems, and most importantly the weaknesses of the systems. Research will then be conducted on the identified weaknesses and RFID solutions that could address these weaknesses. Due to the scope of this project, the team will also investigate existing RFID systems in use around the globe. This research will be the primary way of obtaining information on new solutions to the challenges faced by the existing systems.

In order for a smart parking system to be implemented properly, the system needs to be intelligent. Intelligent systems are created by funneling important data into the system for it to then make decisions based on mathematical algorithms. This data is crucial to the functionality of a system; however it also can be used to create statistics for the managers of the system. The statistics could be used to better optimize the systems by revealing ongoing trends. The team will explore opportunities to improve the current data systems that are in use through RFID implementation. This process is outlined as follows:

1. Determine vehicle data currently in use.
2. Discover areas of improvement.
3. Determine vehicle data needed for functionality goals of an improved system.
4. Explore RFID integrations that address the areas of improvement.
5. Research data availability and privacy concerns of involved parties.

In order to arrive at the final recommendations, the team will combine the research on existing RFID systems and vehicle data to propose an RFID-based intelligent parking management system that improves traffic efficiency and everyday life.

3.2.3 Verify Feasibility of Discovered Solutions

In order to verify the feasibility of potential solutions, the team will compile a list of criteria that deem a solution feasible. An example of these requirements is broken down as follows:

	Is it within budget?	Does it follow laws & regulations of Hangzhou?	Is it scalable across Hangzhou?	Is it existing technology?	Are there any RFID hardware limitations?	---
Solution 1						
Solution 2						
Solution 3						
Solution 4						
...						

Table 2: Feasibility Table

These criteria are subject to change upon completion of the interviews, surveys, and observations. Supporting evidence from the consultations will be used to add new criteria necessary to characterize a solution as feasible. Further research conducted on-site will also alter the requirements of a new system to be tailored towards the end goal. The purpose of the feasibility assessment is to confirm that a proposed solution is able to be implemented, before considering the effectiveness of a solution. Due to this purpose, the feasibility assessment will filter potential solutions into more realistic solutions. At this point, the team will have reached recommendations valid for further research and analysis before presenting to our sponsor.

3.3 Objective Three: Present Recommendations on New or Improved Smart Parking Systems

The team will use a SWOT analysis and cost-benefit analysis to compile and synthesize the data from previous sections. This data will include background research, surveys, interviews, naturalistic observations, collected data and the derived feasible solutions. The synthesized solutions will be evaluated for their strengths and weaknesses. Final surveys will be conducted based on the proposed solutions and subsequently supported by background research completed on-site. The final recommendation will be presented to the sponsors through a presentation and Interactive Qualifying Project written report.

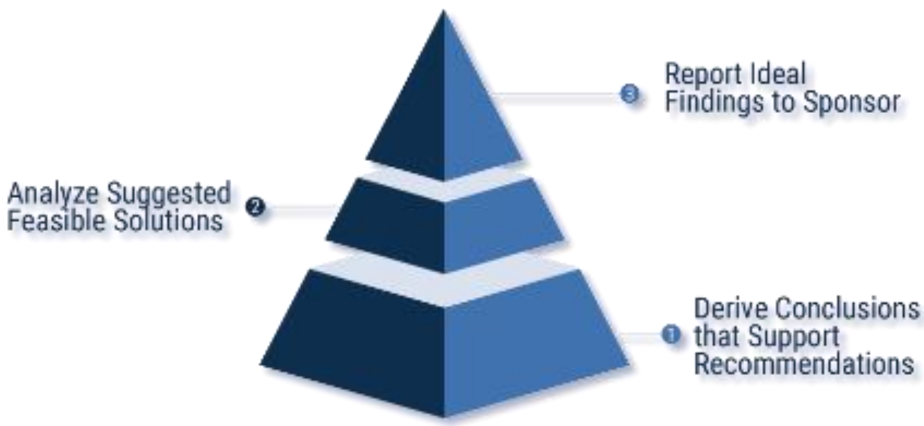

Figure 8: *Objective Three Flowchart*

3.3.1 Analyze Feasible Solutions

After confirming that solutions are feasible based on research and evidence, our team will analyze each individual solution. The analysis will assist in determining which solutions would be the best recommendations. The analysis methods that will be used are the SWOT analysis and a cost-benefit analysis. In addition, the team plans to develop potential scenarios that illustrate how these solutions could be used in real life applications. With this in mind, our team expects to develop a holistic view of each solution that can used to draw final conclusions.

The objective of the team's SWOT analysis is to identify strengths, weaknesses, opportunities, and threats of each individual solution. Furthermore, a key aspect of the SWOT analysis is the breakdown of the internal and external factors that directly or indirectly affect the solutions. The SWOT Analysis format the team intends to use can be seen in figure 4. The table contains four categories that will contain the qualifying factors. The team will review the listings of the SWOT analysis and determine which solution is most applicable in improving Hangzhou's parking system.

Figure 9: SWOT Analysis Table

The second analytical method our team will be utilizing is the cost-benefit analysis, a template of which can be found in appendix C. This analytical method determines the desirability of the proposed solution by weighing the inherit costs against the corresponding benefits. This approach is simple, yet it effectively distinguishes the monetary value of a solution. The value is computed as a ratio that can be compared to determine the value relative to other solutions. The monetary values will include facility costs, labor costs, housekeeping costs, infrastructure, electric bill, and damage costs. The benefits will be further developed once reaching the project center.

3.3.2 Derive Conclusions that Support Recommendations

To support the recommendations, the team will begin by conducting background research on-site to determine the strengths of each solution. Research questions that will be investigated:

- Does a similar system exist? If so, what are the weaknesses?
- What benefits could the recommendations bring?
- What problems could arise from the new system?

- What effects would the recommendations have on the stakeholders?
- Are there better solutions currently being researched?

To further support the recommendations, the team will conduct a survey of the public regarding the proposed recommendations. This survey will be intended to conclude the public's view on what recommendations would be most supported. This information will narrow down the scope of final recommendations to solutions that are widely supported. Once the team conducts this research and a public survey, the team will construct real-life scenarios to visualize different effects of different recommendations.

3.3.3 Report Ideal Findings to Sponsor

Upon completion of the project's objectives, the team will conclude by presenting the findings to the sponsor in the form of a presentation and written report addressing the recommended smart parking solutions. The team will discuss the benefits and social impacts of each suggested recommendation, along with a supporting SWOT and cost-benefit analysis.

The report will include information about the proposed technical designs, along with supporting visual documentation of potential system logistics. Most importantly, the report will outline the general public's view of the recommendations that are presented.

These deliverables will be to the project sponsor, who will subsequently be able to propose the suggestions to parking system managers, authorities and other stakeholders. These stakeholders can further use the recommendations to influence unified smart parking systems that further improve the everyday life of Hangzhou citizens.

3.4 Summary

This project's mission is to study modern RFID technologies and suggest possible improvements to the smart parking solutions in Hangzhou, China. To accomplish this goal, the team will perform observations and interviews in order to develop an understanding of the current smart parking systems and their challenges. The data collected will provide insight to the needs of the consumers and providers of parking solutions. The team will develop considerations that influence the research of RFID smart parking solutions that would be feasible within Hangzhou. The team will use the research to qualify potential solutions which will be analyzed for their feasibility and social impact in the city of Hangzhou. The optimal solutions will be derived through supportive analysis consisting of a cost-benefit analysis and SWOT analysis. The team will prepare recommendations that consist of improvements to the RFID smart parking system which aim to alleviate city congestion and improve everyday life.

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

Bai, Y. B., Wu, S., Wu, H., & Zhang, K. (2012). Geospatial Science Research_2. Overview of RFID-based indoor positioning technology. Retrieved September 13, 2018. Big Data. (n.d.). Retrieved from http://sandhill.com/article/is-data-decentralization-the-new-trend/

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

Bonsor, K., & Fenlon, W. (2007, November 05). How RFID works. Retrieved 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, 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 Def Con 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

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/

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

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

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

Eirini Eleni Tsiropoulou, John S. Baras, Symeon Papavassiliou & Surbhit Sinha (2017): RFID-based smart parking management system, Cyber-Physical Systems. Retrieved August 8, 2018. doi:10.1080/23335777.2017.1358765

Fabian, B., Gunther, O., & Ziekow, H. (2010). RFID and the Internet of Things: technology, applications, and security challenges. ResearchGate,4. Retrieved September 13, 2018. 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 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 from http://hznews.hangzhou.com.cn/jingji/content/2018-01/18/content_6776409.htm

Griffinger, R., & Haindl, G. (2007). Smart cities ranking: an effective instrument for the positioning of cities?(p. 708). Barcelona: University of Technology Vienna. Retrieved September 8, 2018, from https://core.ac.uk/download/pdf/41793309.pdf

Glasmeier, A., & Christopherson, S. (2015). Thinking about smart cities. Cambridge Journal of Regions, Economy and Society,8(1). Retrieved September 5, 2018, from https://doi.org/10.1093/cjres/rsu034.

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/

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/

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. Retrieved September 17, 2018. 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 - IEEE Conference Publication. Retrieved August 28, 2018. doi:10.23919/ICACT.2018.8323770

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/

Madhani, A. (2017, June 06). Chicago cabbies say industry is teetering toward collapse. Retrieved from https://www.usatoday.com/story/news/2017/06/05/chicago-cabbies-say-industry-teetering-toward-collapse/102524634/

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. 2010 Sixth International Conference on Intelligent Environments, 332-337.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/

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/

Roberti, M. (2014, July 14). Which RFID system is right for managing parking areas? [Web blog post]. Retrieved August 6, 2018, from https://www.rfidjournal.com/blogs/experts/entry?11098

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

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/

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

Vesco, Andrea Ferrero, Francesco. (2015). Handbook of research on social, economic, and environmental sustainability in the development of smart cities.IGI Global. Retrieved from https://app.knovel.com/hotlink/toc/id:kpHRSEESD3/handbook-research-social/handbook-research-social

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

Z. Pala and N. Inanc, "Smart parking applications using RFID technology," 2007 1st Annual RFID Eurasia, Istanbul, 2007, pp. 1-3.doi: 10.1109/RFIDEURASIA.2007.4368108

Appendix A: Stakeholder Interview Questions

INTERVIEW QUESTIONS

Pedestrians and Citizens Nearby Parking Spaces

1. What type of transportation do you usually use? Which type of transportation do you prefer (subway, bus, car, bicycle, on foot, etc.)?
    - Subway [ ]
    - Bus [ ]
    - Car [ ]
    - Taxi [ ]
    - Bicycle [ ]
    - On Foot [ ]
2. Do you own a vehicle?
    a. Positive
        i. Have you ever noticed this parking complex?
        ii. Have you ever used this parking complex?
        iii. What services would you expect this parking complex to have?
    b. Negative (Skip to Question 3)
3. Do you walk through here every day?
4. Do you think congestion is common around this area? (Choose all that apply)
    - Human Congestion [ ]
    - Car Congestion [ ]
5. Have you seen any accidents occur around this area?
6. Did you know what a “Smart City” is?
    a. Positive
        i. Did you know Hangzhou is a developing Smart City?
        ii. Do you approve of the “City Brain” project developments in Hangzhou?
    b. Negative
        i. Explain the concept of a Smart City.

Public Parking Customers/Users

1. What type of motor vehicle do you own (car, motorcycle, or other)?
        i. Where do you usually park it?
            - Commercial Parking Lots [ ]
            - Private Parking Lots [ ]
            - Shared Parking Lots [ ]
            - Streets [ ]
        ii. Is there a particular reason that you park it there?

- Location [ ]
- Security [ ]
- Comfortability [ ]
- Technology [ ]
- Price [ ]
- Availability [ ]
- Other [ ]

2. Do you work or live near the area you park?
3. Have you noticed any substantial traffic around this area?
    a. Positive
        i. What days are most problematic?
            - Monday [ ]
            - Tuesday [ ]
            - Wednesday [ ]
            - Thursday [ ]
            - Friday [ ]
            - Saturday [ ]
            - Sunday [ ]
        ii. What time of the day is most problematic?
            - Morning (7:00 ~ 10:00) [ ]
            - Noon (10:00 ~ 14:00) [ ]
            - Afternoon (14:00 ~ 17:00) [ ]
            - Evening (18:00 ~ 20:00) [ ]
            - Late Night (21:00 ~ 24:00) [ ]
            - Midnight (24:00 ~ 7:00) [ ]
4. Are you aware of any technology that the parking space uses?
    a. Positive
        i. Do you think the features this parking space uses are sufficient?
5. Have you experienced any issues when parking? If so in what areas?
    i. Services [ ]
    ii. Parking spaces [ ]
    iii. Technology [ ]
6. Do you consider finding parking spaces around this area easy?

0 1 2 3 4 5 6 7 8 9 10

Very Difficult Moderate Very Easy

7. Do you think finding your own car after parking it is easy?
8. Do you think an app that helps you find parking spaces and(or) your car is useful?

Public Parking Space Personnel

1. What is your main role?
2. What shortcomings of the parking system affect your daily job?
3. What does the complex excel in?
    - Location [ ]
    - Security [ ]
    - Comfortability [ ]
    - Technology [ ]
    - Price [ ]
    - Availability [ ]
4. What features do you think are the most important of a parking complex?
    - Location [ ]
    - Security [ ]
    - Comfortability [ ]
    - Technology [ ]
    - Price [ ]
    - Availability [ ]
5. What features would you think could improve this parking complex?
6. Rate the efficiency of the parking complex currently on a scale of 0 - 10.

0 1 2 3 4 5 6 7 8 9 10

Inefficient Moderate Very Efficient

Public Parking Space Managers

1. What system does your parking complex use (simple RFID system, robotic system, camera system, etc.)?
2. (Do you know) Who is the system service provider?
3. Does this system keep track of the number of cars that enter the complex?
4. Does this system use RFID technology?
5. How effective is this system in peak hours?

0 1 2 3 4 5 6 7 8 9 10

Ineffective Moderate Very Effective

6. Where does this parking complex face the most challenges?
    - Location [ ]
    - Security [ ]
    - Comfortability [ ]
    - Technology [ ]
    - Price [ ]
    - Availability [ ]

7. What features are the most useful in this system?
    a. Ease of use
    b. Complexity
    c. Maintenance
    d. Security
8. What features do you think your system lacks or should have?
9. Are you aware of your customer satisfaction levels (personal surveys, customer reviews, etc.)?
10. Have you received any complaints with the current system?
11. How many people are employed in this complex?
12. Rate the efficiency of the parking complex on a scale of 0 - 10.

0	1	2	3	4	5	6	7	8	9	10
Ineffective					Moderate					Very Effective

Researchers & Graduate Students

1. What RFID technology is currently used in Hangzhou? Give examples.
2. What RFID technology is being researched within Hangzhou that you know of?
3. Are you aware of other non-RFID technologies?
4. What parking system has been used the most in China?
5. What system are you currently researching?
6. Does your system use IoT technologies?
7. What are the main issues with the current system?
8. Currently, what type of data is being stored within the parking management systems?
9. What data can be stored within the parking management systems?
10. What methods are being used to gather the data from vehicles?
11. Does the public or the government have access to the data in the system you are researching?
12. What statistics might be helpful in evaluating these solutions?
13. What criteria needs to be satisfied for a feasible solution?

Tech Companies/Experts

1. Around how many systems has your company developed for parking management? Or have you focused on one system throughout the years?
2. What would you consider your system to excel in? Select all that apply.
    - Efficiency [ ]
    - Ease of use [ ]
    - Flexibility [ ]
    - Price [ ]

- Other [ ]

3. What technology does your cheapest system use?
4. What technology does your most expensive system use?
5. Have you considered the use of RFID technology in any of your systems?
    a. Do you think it is a secure technology?
    b. What are its pros and cons?
    c. If you use RFID technology, what is it main purpose?
6. When looking at a solution, what are some key factors when developing the system for the solution?
7. What type of data is stored in your systems?
8. Where are your systems usually installed (downtown, center or surroundings of urban cities)?
9. What sets your system apart from competitors?
10. Does your system use IoT technologies?
11. Is your system scalable?

Government Officials

1. Is congestion one of the government's concerns?
2. What is the role of the government in public parking complexes and spaces?
3. What are the laws regarding data from public parking complexes and spaces?
4. On a scale of 0 ~ 10, what is the government's interest in smart city development?

0 1 2 3 4 5 6 7 8 9 10

Not Interested Moderate Very Interested

Appendix B: Informed Consent Form

INFORMED CONSENT STATEMENT

Greetings, we are a group of students from Worcester Polytechnic Institute (WPI) located in the United States. We are interviewing public parking spaces personnel and tech companies in order to understand the challenges and perspectives of the current public parking systems. Our hope is that we will ultimately create a feasible solution that could further the development of an RFID-based intelligent city parking management system.

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 where necessary, if the team chooses to.

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

Appendix C: Cost-Benefit Analysis Template

COST BENEFIT ANALYSIS TEMPLATE

benefit cost ratio = Net Benefits/ Net Cost								
Cost-Benefit Analysis								
Costs (Monetary Values)	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Total:**
Facility Costs								*add rows
Labor Costs								
Housekeeping Costs								
Infrastructure								
Electric Costs								
Damage Costs								
Total:	*add columns							
Benefits (Assign Monetary Value)	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Total:**
Safety From Elements								*add rows
Protection From Scratches and Bumps								
Ease of Accesses								
Likelihood of Vandalism								
Total:	*add columns							

								Total:
Benefit Cost Ratio:	*each column ratio							